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EARLY LIFE HISTORY OF PACIFIC HERRING: RELATIONSHIPS OF LARVAL DISPERSAL AND MORTALITY TO ENVIRONMENTAL CONDITIONS

FINAL REPORT OF 1989 PORT MOLLER RECONNAISSANCE SURVEY

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Abstract

A reconnaissance of the plankton community of Port Moller, Alaska, in June, 1989, found that it contained enough Pacific herring, Clupea harengus pallasi, larvae to justify a large-scale study of their population dynamics.

At least 3 cohorts of herring larvae hatched into Port Moller between May 1 and June 30, 1989. Cohort 1 hatched on May 29, 1989, from eggs spawned on May 15 and cohort 2 hatched on June 10-11 from eggs spawned on May 27-29. A third cohort was expected to hatch into the water column in late June because a third group of adult herring was the target of a mid-June commercial sac-roe fishery in Port Moller.

Cohort 2 was composed of 2 groups of larvae separated by about 0.8 mm in average length. The group of larger fish was most abundant and it was concentrated at the head of Moller Bay. The group of smaller fish was less abundant and it was concentrated at the head of Herendeen Bay. The difference in size and age between the 2 groups may have been caused by lower water temperatures in Herendeen Bay than in Moller Bay. Growth of larvae was significantly higher in Moller Bay, 0.25 mm d^{-1}, than in Herendeen Bay, 0.12 mm d^{-1}.

Cohort 1 consisted of 3.1 $143x10^8$ larvae with a mean age of 14 d, and cohort 2 consisted of $7.0641x10^9$ larvae with a mean age of 5 d. The biomass of the spawners that produced cohort 2 was estimated by back-calculation from the number of 5 d old larvae to have been 1,788 to 2,241 MT. This was 1 to 27% higher than the spawning biomass estimated from aerial surveys, 1,764 MT.

The mean density of herring larvae in Port Moller was 15 times greater than the mean density of herring larvae measured in Auke Bay, Alaska, in 1988. The biomass of spawners that produced cohort 2 was at least 130 times larger than the largest spawning biomass estimated for Auke Bay in 1988. These numbers show that the abundance of herring in Port Moller is at least one order of magnitude greater than that measured in Auke Bay. Therefore, phase II of this contract, development of a quantitative model of herring transport, is recommended to proceed.

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1.0 Introduction

This is the final report of the 1989 reconnaissance survey of Port Moller, Alaska. The objectives of the survey were to measure the densities of Pacific herring, Clupea harengus pallasi, larvae and map herring spawning habitat in order to determine whether Port Moller would support a large-scale study of the population dynamics of herring larvae. This survey reports that sufficiently high concentrations of herring larvae were found to justify such a study.

McGurk (1989b) recommended that studies of herring larvae in the Bering Sea be based in an area that has consistently received large amounts of spawn, arbitrarily defined as greater than 2.5 linear km of spawn. However, it is difficult to measure the magnitude of herring spawn in the Port Moller estuarine complex because of the poor 'seeing' conditions. In the 8 yr that the Alaska Department of Fish and Game (ADFG) has been conducting aerial surveys in Port Moller only the surveys flown in 1989 are thought to have provided accurate assessments of spawning biomass (personal communication, L. Schwarz, ADFG, Division of Commercial Fisheries, 211 Mission Road, Kodiak, Alaska 99615). This is because frequent rain, fog and high winds often prevents aerial surveys. Even in good flying conditions schools of adult herring and clouds of milt are difficult to see because strong tidal currents in the shallow water create a coffee-colored mixture of water and silt that obscures vision. The presence of flocks of shore birds is not a good indicator of the presence of herring spawn in Port Moller because, unlike southeast or southcentral Alaska, the spawn in Port Moller is laid on sub-tidal vegetation because winter ice scours intertidal vegetation.

This situation is encountered in other fisheries in which eggs are inaccessible because they are either deposited on the seafloor at depths of 10 m and greater or because the adults retain the eggs until they hatch. In these cases stock size may be estimated by back-calculation from the densities of newly-hatched larvae. Stock size of Atlantic herring, Clupea harengus pallasi, in the North Sea has been calculated from the number of larvae (estimated from plankton surveys) using a linear regression of stock size [estimated from virtual population analysis (VPA)] on larval abundance (Postuma and Zijlstra 1974, Saville 1981, Burd 1985), but this method can only be applied to those stocks for which sufficient information is available on commercial catches and age structure to perform a VPA, and for which at least 3 yr of plankton surveys are available. Neither of these requirements are met for the Port Moller stock of Pacific herring.

A second method of estimating stock size is to back-calculate it from larval abundance using a model of the population dynamics of the egg and larval stages. This method only requires a single survey of larval abundance, but the survey must cover the entire area occupied by the larvae. The method also requires accurate estimates of mortality during the egg and larval stages. The difficulties involved in ensuring complete spatial coverage of the larvae, and of measuring the mortality rates of the eggs and larvae has restricted the utility of this method. Sinclair et al. (1979; cited in Auger and Powles 1980) first attempted to use it to estimate the size of the Atlantic herring stock of the Bay of Fundy, and Auger and Powles (1980) used it to estimate the size of the stock of Atlantic herring near Isle Verte in the St. Lawrence estuary. Both attempts were inconclusive because of uncertainty about the egg and larval mortality rates.

However, recently Nichols et al. (1987) was successful in using this method to estimate the stock size of Norway lobster, Nephrops norvegicus, in the western Irish Sea. A key factor in their success was the accurate measurement of larval mortality rate. In the last decade much information has become available on the probable ranges of mortality rates of eggs and larvae of Pacific and Atlantic herring. In this report, I use this method in order to estimate spawning stock size of Pacific herring in Port Moller.

This report includes a brief review of the available biological information on the herring of Port Moller. This was done in order to estimate the number of spawning runs and their approximate dates, to derive estimates of parameters used in the population model, and to define the limits of scientific knowledge about this stock.

2.0 Study site

The Port Moller estuarine complex is the largest embayment on the northern shore of the Alaska Peninsula (Fig. 1). It has a total surface area of 876 km^2 enclosed in 4 shallow bays: Moller Bay, Mud Bay, Herendeen Bay, and Nelson Lagoon. Mean depth at lower low tide ranges from 4 to 17 m, except at the head of Herendeen Bay, where mean depths of 35 to 45 m are encountered.

Extensive mud flats occur in Nelson Lagoon, Mud Bay and along the southern shores of Moller and Herendeen Bays. At low tides the former bays are impassable and the rest of Port Moller can only be navigated through narrow channels. The mud flats are strewn with boulders, and, near the shore, with large eelgrass beds.

Sears and Zimmerman (1977) report that the intertidal zones of Nelson Lagoon and Mud Bay consist primarily of mud, and those of Herendeen and Moller Bays consist primarily of gravel with some mud and bedrock. The shore northwest of the entrance to Port Moller up to the mouth of Bear River is a long sandy beach.

The tidal range within the Port Moller compex is estimated to be 3 m, and tidal currents are relatively strong, reaching maximum ebb and flood velocities of approximately 150 cm s^{-1} (U.S. Department of Commerce).

The area surrounding Port Moller is remote and sparsely inhabitated. The native community of Nelson Lagoon (population: 500) is established on the barrier islands of Nelson Lagoon. The Peter Pan Seafoods fish processing plant (staff: 200) operates at Entrance Point from May to September of every year.

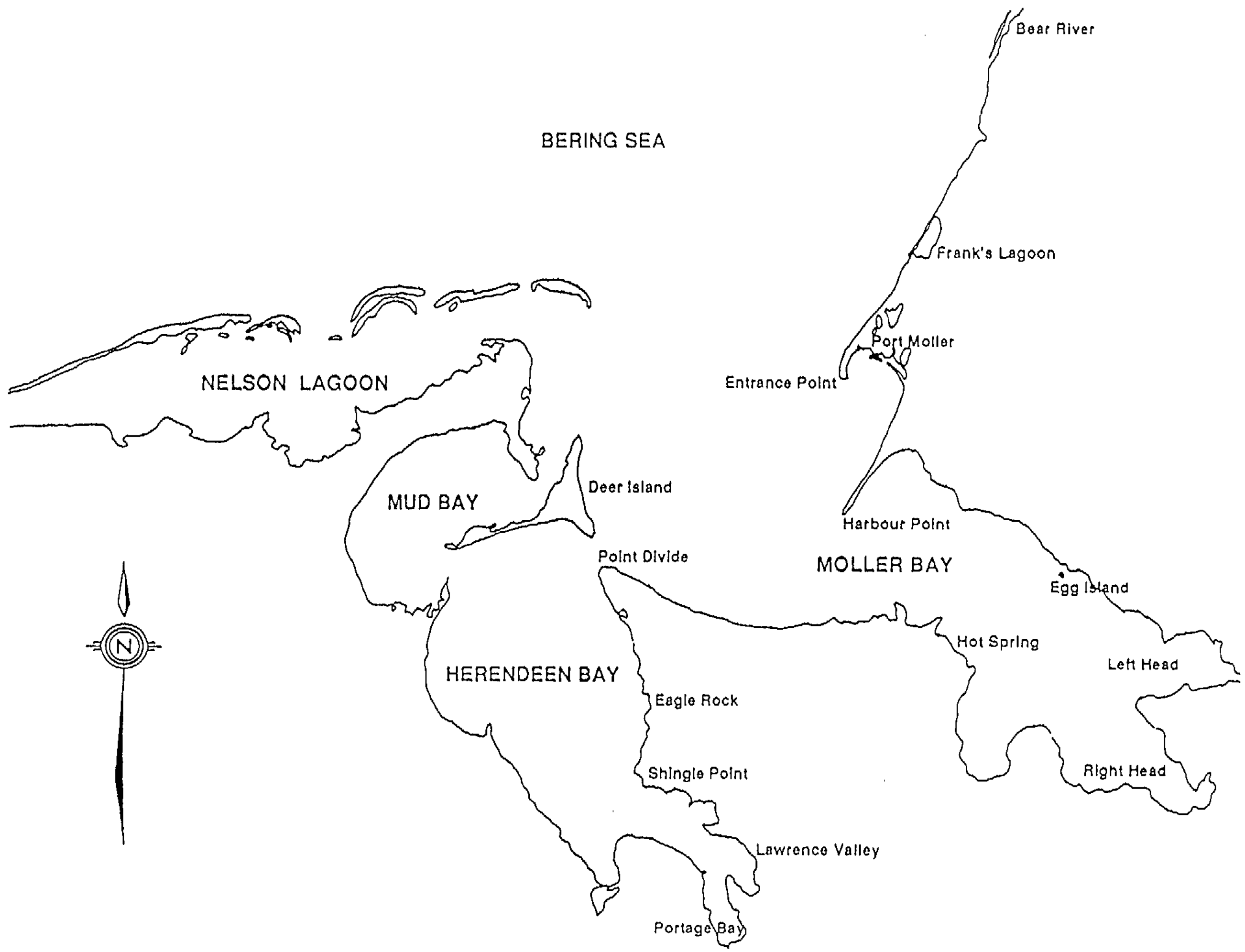


Fig. 1. Map of Port Moller.

3.0 Materials and methods

3.1 Review of Port Moller herring biology

Information on the herring of Port Moller was obtained from two sources: Annual Reports of the Alaska Peninsula - Aleutian Islands management area written by biologists of the Division of Commercial Fisheries of the Kodiak office of ADFG; and by a search of the scientific literature on fish and fisheries of the Bering Sea.

3.2 Aerial surveys of spawning biomass

ADFG estimates spawning biomass in the Port Moller area with aerial surveys. The methodology of these surveys is described by Anonymous (1986). Observers fly at an altitude of about 450 m and count the number of schools of herring and measure the length and width of each school. The surface ties of each school is the product of the length of the school and its width. Each school is classified into one of three size classes based on its surface area: small schools with an area< 50 m^2; medium-sized schools with a surface area > 50 m^2 and< 450 m^2; and large schools with a surface area >450 m^2. The number of schools in each size-class is converted to Relative Abundance Indices (RAI) by assuming that 1 small school = 1 RAI, 1 medium-sized school = 5 RAI, and 1 large school = surface area/50 m^2. Aerial observers also classify the 'seeing' conditions on each date with a 5-point rating system 1 = excellent, 2 = good, 3 = fair, 4 = poor, 5 = unsatisfactory.

Biomass of herring measured in one survey is calculated as

$$(I) \qquad B_Y = \sum^{I} \sum^{J} RAI_{Yij} \; b_j$$

where By = spawning biomass (MT) observed on Julian date Y, RAI_{Yij} = the number of relative abundance units observed in the jth depth class of the ith area of Port Moller on date Y, and b_j = a conversion factor having values of 1.38 MT RAI^{-1} for schools in water 5 m deep or less, and 2.34 MT RAI^{-1} for schools in depths greater than 5 m. Conversion factors were calculated from surveys of schools of known biomass and surface area in known water depths that were conducted with chartered commercial fishing vessels in Bristol Bay in 1983. If more than one survey of Port Moller was conducted in a single day, then the largest number of RAIs recorded in each of the ith areas was chosen as the most accurate index of biomass, rather than the mean number of RAIs, because the observers were more likely to underestimate the number of schools than they were to overestimate the number.

3.3 Plankton sampling

Fifteen plankton stations in Port Moller were sampled at least once during the reconnaissance survey. Fig. 2 shows the locations of the stations and Table 1 lists their code letters, geographic locations, and positions along the major axes of the Bays.

The first step in defining the axes was to divide the Port Moller complex into 2 parts: Moller Bay and the Bering Sea; and Herendeen Bay. This was necessary because the length frequency distributions of the herring larvae, the spatial distribution of the percent yolk sacs, the growth rates, and the densities of the larvae showed that the population dynamics of the larvae in Herendeen Bay were different from the dynamics of the larvae in the rest of the Port Moller complex.

The second step was to define an x-coordinate for each sampling station within a part. This was done by, first, defining the geographic center of each section and connecting the centers of adjacent sections with straight lines. The origin of the x-axis in Moller Bay was the midpoint of a line drawn across the base of the peninsula separating the Left and Right Heads of Moller Bay. The origin of the x-axis in Herendeen Bay was the head of Portage Bay. The distance between a station and its origin was measured by dropping a perpendicular line from the station to the nearest comecting axis, and then following the shortest distance to the origin along the connecting axis.

Table 1 also lists the total area of the section surrounding each station, the portion of this area that is below lower low tide, and the portion that is intertidal. It also lists the mean ($\pm$ lSD) depths of the subtidal portion of each section. The boundaries of the sections were created by drawing lines at an equal distance between adjacent stations. In most cases, the lines were oriented perpendicular to the major axis of each bay. Areas were measured by planimetry from hydrographic map number 16363 produced by the U.S. National Ocean Survey (NOAA). The mean depth of the subtidal portion of each section was calculated from soundings taken at mean lower low tide that are shown on the hydrographic map. The depth of each section at the time its central station was occupied was calculated by adding the average depth shown in Table 1 to the water depth above lower low tide due to the average stage of the tide at the time that each plankton sample was taken (Table 8). Therefore, the volume of water present in each section at the time it was sampled was

$$(2)\quad V_{,i} = A_{Si} (H_{Si} + H_{ti}) + A_{Ii} H_{ti}$$

where V_{ti} = total volume (m^3) of water in section i at time t, A_{Si} = area (m^z) of subtidal portion of section i, A_{Ii} = area (m^2) of intertidal portion of section i, Hs_i = mean depth

Fig. 2. Map of plankton stations

Table 1, Plankton stations in Port Moller.

Site code	Site description	Latitude	Longitude	Section area (m^2) sub-tidal	inter-tidal	total	Section depth (m) mean	SD	n	range	x-coordinate (m) Moller	Herendeen
Upper Moller Bay												
A	off entrance to Left Head	5550'15"	16019'10"	28917525	48498450	77415975	4.4	5.2	94	15.2	7980	
B	off Egg Island	5552'45"	16024'15"	21526050	34234200	55760250	6.0	5.1	65	19.8	14763	
c	off Hot Spring	5553'28"	16029'15"	28074637	10438838	38513475	5.6	6.1	97	25,6	19670	
D	inside Harbor Point	5554'20"	16034'20"	24184387	19256725	43441125	6.4	11,7	70	67,7	25935	
Lower Molter Bay												
E	between Harbor and Entrance Points	5556'58"	16035'20"	49017150	9077250	58094400	6.1	6,3	225	47.5	30962	
J	between Deer Island and Harbor Point	55 56'03"	160 42'05"	68727750	56473462	125201212	5.6	6.1	293	42.1	36149	
Bering Sea												
F	1 km off Entrance Point	5559'22"	16037'06"	95246287	972563	96218850	8.2	5,2	280	23.8	36069	
G	10 km off Entrance Point	5505'25"	16042'34"	216946275	0	216946275	17.2	5,3	205	29.3	46358	
H	off center of Frank's Lagoon	5603'46"	16031'49"	75730200	0	75730200	8.0	4,0	133	17.4	45805	
I	off mouth of Bear River	5609'45"	16027'00"	35660625	0	35660625	9.6	6.5	73	20.1	57935	
Herendeen Bay												
K	inside Point Divide	5552'47"	16050'18"	58548262	69440962	127989225	6.0	10.3	175	95,1		24100
L	off Eagle Rock	5549'45"	16046'52"	26907562	34623225	61530787	3.8	5.1	148	29,3		18035
M	off Shingle Point	5546'42"	160 46'13"	37929937	4733137	42663075	16.4	14.6	119	60.4		11252
N	off Lawrence Valley	5544'28"	16040'36"	8234362	778050	9012412	45,4	28.6	36	104.2		4389
0	center of Portage Bay	5543'00"	16041'08"	6548587	324187	6872775	33.9	25.1	20	69.5		1676
			Total	782199596	288851049	1071050661						
Mud Bay					0	55500900	55500900					
Nelson Lagoon					0	174801900	174801900					
			Total	782199596	519153849	1301353461						

(m) of subtidal portion, H_{ti} = depth (m) above mean lower low tide at time t due to the daily tidal cycle.

Plankton samples were taken with 3 m long bongo nets each having a mouth diameter of 0.6 m, a mesh width of 333 μm and a hard plastic codend. The nets were towed at approximately 1 to 2 m see-l in a double oblique pattern from the surface to 30 m, or to the midpoint of the water column if the water was less than 30 m deep, and then back to the surface. A General Oceanics mechanical flowmeter was placed off center in one of the two nets in order to measure the volume of water filtered in a tow. The contents of the codends were preserved immediately in 5% formaldehyde and seawater. All of the plankton samples were collected between 0800 and 1900 h.

Temperature and salinity profiles were measured with a conductivity-temperature meter at each station immediately after each tow.

All fish larvae were sorted from the preserved plankton under a dissecting microscope. Herring larvae were counted and abundance was expressed as number per m^3 filtered by the nets. The densities of newly-hatched herring larvae are expected to be reliable measures of their true density, but the true density of mid- and large-size fish larvae is known to be underestimated by plankton nets catches because these fish are large enough to detect and evade the net. The measured densities of herring larvae were corrected for evasion of the plankton net using McGurk's (1989a) equation

(3) $N_{ti} = n_{ti} 0.1355 \exp(0.270 L_{ti})$

where N_{ti} = density (m^{-3}) at time t and site i corrected for net evasion, n_{ti} = measured density (m^{-3}) at time t and site i, and L_{ti} = length (mm) of larvae at time t and site i. This equation was derived from the ratios of night to day catches of Pacific herring larvae captured in Bamfield Inlet, British Columbia. The rationale for the use of this equation is described in Appendix F of this report.

Standard lengths of 100 randomly-chosen herring larvae from each sample were measured with an ocular micrometer. Length was corrected for shrinkage caused by capture in a towed net using a Gompertz model calibrated for Pacific herring larvae by McGurk (1985).

Larvae were assigned to cohorts based on their body length. The number of cohorts and the average lengths of the fish in each cohort at each sampling date were identified by examination of length frequency plots. It was assumed that the number of fish was normally distributed with length.

The average age of larvae in a sample that contained at least one yolk sac larva was calculated from the fraction of the sample that retained a yolk sac. The procedure was based on the fact that the number of days from hatching to exhaustion of the yolk sac of Pacific herring larvae decreases exponentially with temperature. Alderdice and Velsen (1971: Table 4) reported times from hatching to yolk exhaustion for 12 combinations of salinity and temperature. Response surface analysis showed that the times were not significantly related to salinity, and that the best relationship with temperature was

$$(4)\quad Y = 40.9T^{-0.84}$$
$$r^2 = 0.67,\ n = 12,\ P= 0.001,\ SE_b = 0.19$$

where Y = time from hatching to yolk exhaustion (d) and T = temperature (°C) (Fig. 3). Therefore, the age of a sample containing any yolk sac larvae was

$$(5)\quad t_i = 40.9T_i(1 -f)$$

where t_i = age (d) of a sample taken at site i, T_i = mean temperature (°C) of the upper 30 m of the water column at site i, and f = the fraction of sample consisting of yolk sac larvae. Mean temperature was assigned on the basis of where the larvae were captured. Age of larvae captured in Upper Moller Bay and Herendeen Bay was calculated from the respective mean temperatures of those Bays, but the age of larvae captured in Lower Moller Bay was calculated from the mean temperature of both Upper and Lower Moller Bays, and the age of larvae from the Bering Sea was calculated from the mean temperature of the Bering Sea and the entire Port Moller complex.

The mean age of a sample that did not contain any yolk sac larvae was calculated from the mean length of the larvae in the sample using the the growth equation for the area, Moller Bay/Bering Sea or Herendeen Bay, in which the sample was taken.

Growth rate of herring larvae was assumed to be constant

$$(6)\quad L_t = LO + Gt$$

where L_t = length (mm) at age t (d), LO = length (mm) at hatch (t =0), and G = growth rate (mm d^{-1}).

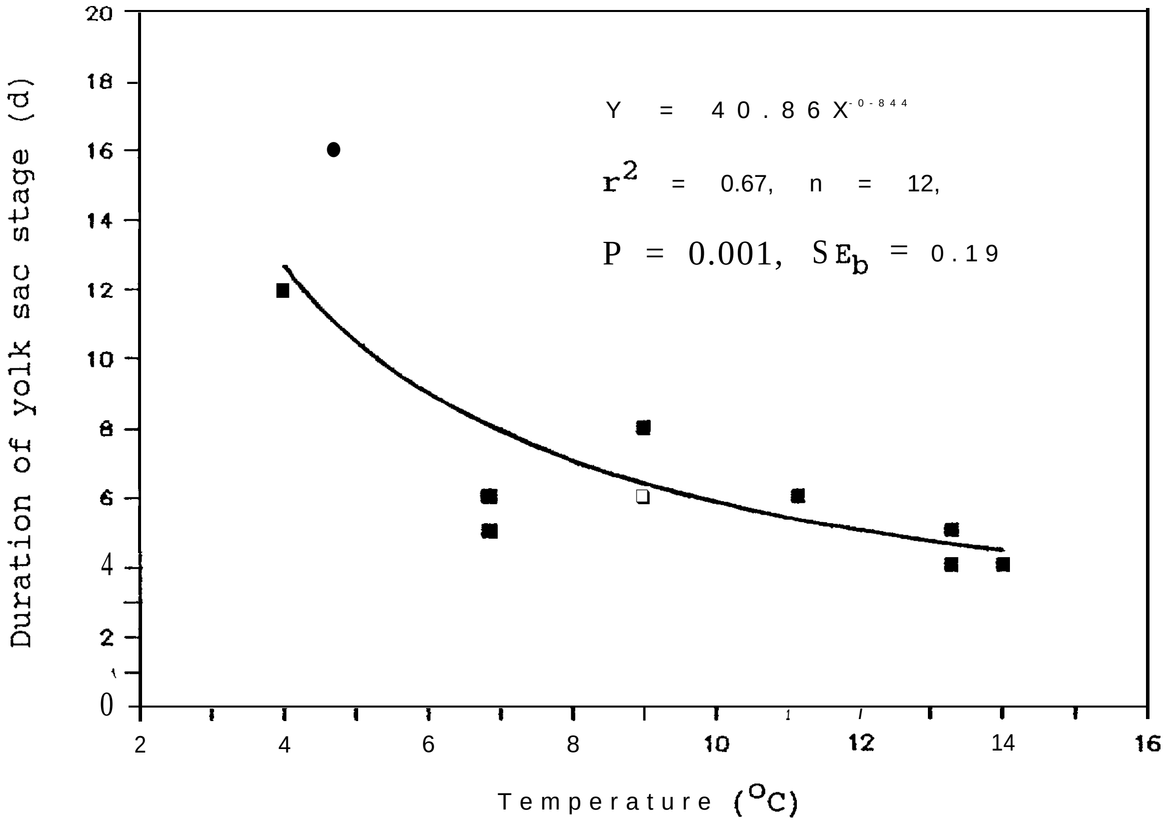


Fig. 3. Temperature-dependence of duration of yolk sac stage [data from Alderdice and Velsen [1971)].

Hatching dates of cohorts of herring larvae were back-calculated from the midpoint of the sample collection dates as

(7) $$Y_H = Y_L - \frac{(L - LO)}{G}$$

where Y_H = Julian date at hatch, and Y_L = Julian date corresponding to the mean length L (mm) of the samples.

Spawning dates were back-calculated from the hatching dates as

(8) $$Y_S = Y_H - \frac{100}{D(T)}$$

where Y_S = Julian date of spawning and D(T) = the daily percent development of the eggs at a mean surface water temperature of T (“C). D(T) was calculated using Alderdice and Velsen's (1971) equation

(9) $D(T) = 0.7448 + 0.4375T + 0.0235T^2$

3.4 Population model

Biomass of adults was back-calculated from the number of eggs as:

(lo) $$B = \frac{2N_e}{10^6 F_r}$$

where B = biomass (MT), N_e = total number of newly-spawned eggs, F_r = relative fecundity (number of eggs/g total body weight). The right-hand side of equation (10) is doubled because a sex ratio of 1:1 is assumed. This is a standard assumption for estimating the stock biomass of Pacific herring from spawn survey data, e.g. Schweigert and Stocker (1988).

N_e was back-calculated from the number of newly-hatched larvae as:

(11) $$N_e = \frac{NO}{s_1 s_2 s_3}$$

where N_0 = total number of newly-hatched larvae, s_1 = fraction of eggs that survive predation during incubation, s_2 = fraction of surviving eggs that hatch larvae, and s_3 = fraction of newly-hatched larvae that are viable. Hatching mortality is assumed to occur only during hatching, so there is no interaction between the three survival rates. s_1 was estimated as

$$(12)\quad s_1 = \exp(-Z_e t_e)$$

where Z_e = instantaneous daily egg mortality (d^{-1}) due to predation and t_e = duration of egg incubations (d), i.e. 100/D(T). Z_e was estimated after a review of measurements of egg mortality in Pacific and Atlantic herring egg beds reported in the scientific literature (section 4.4.1). s_2 and s_3 were also estimated from a review of the scientific literature (section 4.4.1).

N_0 was back-calculated from the number of larvae at age t using two assumptions about mortality rate: that it was constant with age over the early larval period, i.e.

$$(13a)\quad N_t = N_0 \exp(-Zt)$$

where N_t = number of larvae at age t (d) and Z = a coefficient of instantaneous daily mortality (d^{-1}); and that it decayed as a power function of age (Hewitt et al. 1985), i.e.

$$(13b)\quad N_t = N_0\, t^{-\beta}$$

where β = coefficient of instantaneous daily mortality.
Thus, NO is calculated as either

$$(14a)\quad No = N_t \exp(Zt)$$

or

$$(14b)\quad No = N_t\, t^{\beta}$$

The total number of herring larvae at age tin Port Moller was the sum of the numbers of larvae in each section of the area

$$(15)\quad N_t = \sum^{i} N_{ti} Vi$$

where N_{ti} = density (number m^{-3}) of larvae of age t at station i of Port Moller.

N_{ti} was not measured at every station at each date, and in some stations at which it was measured, it was too small to be detected. Therefore, it was necessary to estimate N_{ti} at those stations using a simple application of turbulent diffusion theory (Okubo 1980). Depending on which mortality function is used, the distribution of larvae in each of the two parts of the Port Moller complex should follow the function

$$\text{(16a)} \qquad N_{ti} = \frac{C}{4\pi HKt} \exp\left(\frac{-x^2}{4Kt} - Zt\right)$$

or

$$\text{(16b)} \qquad N_{ti} = \frac{Ct^{-(\beta+1)}}{4\pi HK} \exp\left(\frac{-x^2}{4Kt}\right)$$

where C = the number of larvae hatched per unit volume, H = the mean depth (m), K = the coefficient of radial diffusion ($m^2 d^{-1}$), and x = the distance (m) of a station from the origin of its x-coordinate system.

Equations (16a) and (16b) were fit to the density data by non-linear multiple regression after transformation with natural logarithms. Zero counts were excluded because they could not be assigned an age, and because they do not represent true zero counts but only indicate that that the density of larvae at a station was lower than the limit of detection of the sampling gear. The entire equation was fit to the data, and then if β, Z or K were not significant ($P > 0.05$), the terms that contained these coefficients were removed in a backwards stepwise fashion until a version was derived in which all parameters were significant.

3.5 Location of spawning habitat

Three methods were used in order to locate herring spawning habitat: dredges of subtidal habitat, surveys of beaches at low tide by foot and by all-terrain vehicles, and an aerial survey. A summary of the dredges made in the Port Moller complex, and of the beaches surveyed by foot and motorcycle, was included in the Field Report of the 1989 Port Moller Reconnaissance Survey (Envirocon Pacific Ltd. 1989) and will not be discussed further in this report. One aerial survey of the entire Port Moller complex was conducted at low tide on the afternoon of June 16. This survey was far more effective in revealing the distribution of intertidal vegetation in Port Moller than either of the 2 other methods.

Information on the location of traditional herring spawning beaches, and on the relative frequency of spawning at a site, was obtained from an interview with Warren Johnson of Kenai Float Planes (Nelson Lagoon, Alaska), who has 10 yr of experience flying surveys for herring fishermen in Togiak and Port Moller, and from correspondence with Len Schwarz, assistant ADFG Management Biologist for the Port Moller fishing district.

4.0 Results

4.1 Review of Port Moller herring

4.1.1 Commercial catches

Native subsistence fiiheries for herring and herring food and bait fisheries undoubtedly occurred in the Port Moller area in pre- and post-Contact eras, but they were never adequately documented. Herring are known to have been harvested for food by people living in coastal villages on the northeastern shore of the Bering Sea since at least 500 B.C. (Hemming et al. 1978, cited by Fried and Wespestad 1985). An extensive midden at Hot Spring in Moller Bay indicates that Aleuts and/or Eskimos lived at this site for centuries. Presumably, they also harvested herring for food. Notched stones commonly used as weights on gillnets were found at this site (personal communication, Rae Baxter, NOAA, National Ocean Service, 222 W. 8th Ave., #56, Anchorage, Alaska 99513-7543). Ruins of two fish canneries are visible on the shores at the head of Herendeen Bay. Although their primary focus was canning salmon, they may also have harvested herring for food and bait. The fish processing plant at Entrance Point has operated continuously since the first decade of this century. It freezes some of the herring caught in Port Moller and then ships it to Japan for processing.

Investigation of herring stocks in the Bering Sea only began in 1975 under the Outer Continental Shelf Environmental Assessment Program (OCSEAP). The principal investigator was ADFG. Aerial surveys of the Port Moller area by ADFG personnel in 1976 reported numerous schools of herring in Herendeen Bay (Warner and Shafford 1979). However, aerial surveys conducted from Port Moller to Bering Strait between April 30 and June 28, 1979, did not find any spawning schools along the entire northern shore of the Alaska Peninsula (Barton and Steinhoff 1980). This demonstrates the poor ‘seeing’ conditions which are often encountered on this coast. Since 1984 ADFG field crews have been placed in the Port Moller area where they have caught herring in test nets.

Commercial landings of herring from the Port Moller area were first reported in 1982. Since then an average of 508 (SD = 166, n = 8) MT have been harvested each year in a sac roe fishery (Table 2). More than 70% of the catch was taken from Herendeen and Moller Bays, arid the remainder of the catch was taken off the Bering Sea coast between Entrance Point and the mouth of Bear River.

Table 2. Annual harvest (MT) of Port Moller Pacific herring.

Local ion	1982	1983	1984	198S	19S6	19S7	19SS	19S9	TOTAL	Percent
Deer Island	0	0	0	66	38	0	0	0	104	2.56
Herendeen Bay	254	464	164	91	102	146	7	61	1289	31.73
Molter Bay	164	33	227	233	238	313	259	389	18S6	45.68
Bear River/E. Bering Sea mast	42	74	0	261	430	7	0	0	814	20.03
Total	460	571	391	6S1	808	466	266	450	4063	100.00

4.1.2 Spawning dates

Commercial catches of herring from Port Moller from 1983 to 1988 were landed from May 9 to June 23 (Fig. 4 and Appendix A). With two exceptions, most catches were taken during a time period of 20 d or less. A bimodal distribution of catches with date in 1987 and 1989 indicates that more than one spawning group was harvested in those years: one in mid- to late-May and a second in early-to mid-June. Percent roe yield of the 1987 catches exhibited a similar bimodal pattern (Appendix A), as did the biomass of pre-spawning herring estimated by ADFG's aerial surveys (Appendix B).

Table 3 summarizes the mean dates of earliest possible spawning. These dates were calculated by weighting calendar dates by the amount of commercial landings, or by the percent roe yield, or by the biomass of spawners estimated from ADFG's aerial surveys. Spawning presumably occurs at those mean dates or several days later. Table 3 shows that there are at least two spawning groups that use Port Moller: a group that appears between May 11 and May 29, and a second group that appears between June 2 and June 23, Table 3 also shows that the first group spawns every year in Port Moller, but that the second group apparently only spawns every second year in Port Moller.

These results must be interpreted with caution because they are based on data from the commercial fishery. One of the problems with such data is that no further information is collected once the catch quota has been met and the fishery is closed. Since the quota is usually met within 2 to 3 wk of opening the fishery on the May spawning run, any information on succeeding runs is not collected. Thus, the frequency of occurrence of second or even third spawning runs is most likely underestimated by this data.

4.1.3 Spawning biomass

Appendix B lists the biomass of herring observed by ADFG's aerial surveys in 1984, 1987, 1988 and 1989. There are no estimates of spawning biomass for 1983 and 1986 because bad weather and muddy water prevented the observers from counting any herring schools. The numbers for all years except 1989 are considered minimum estimates because of the poor 'seeing' conditions that are aften encountered in Port Moller. 1989 was an excellent year for aerial observation. It was the first year in which aerial observers were able to see schools of adult herring actually rolling into shallow water to spawn. "

On May 28, 1989, a substantial biomass of herring was spotted by industry aerial observers traveling southwest along the coast of the Alaska Peninsula between Port Heiden and Port Moller. This area was outside the Moller fishery district and so it was open to fishing; a harvest of 225 MT was taken. On May 29, 1989, approximately 1,182

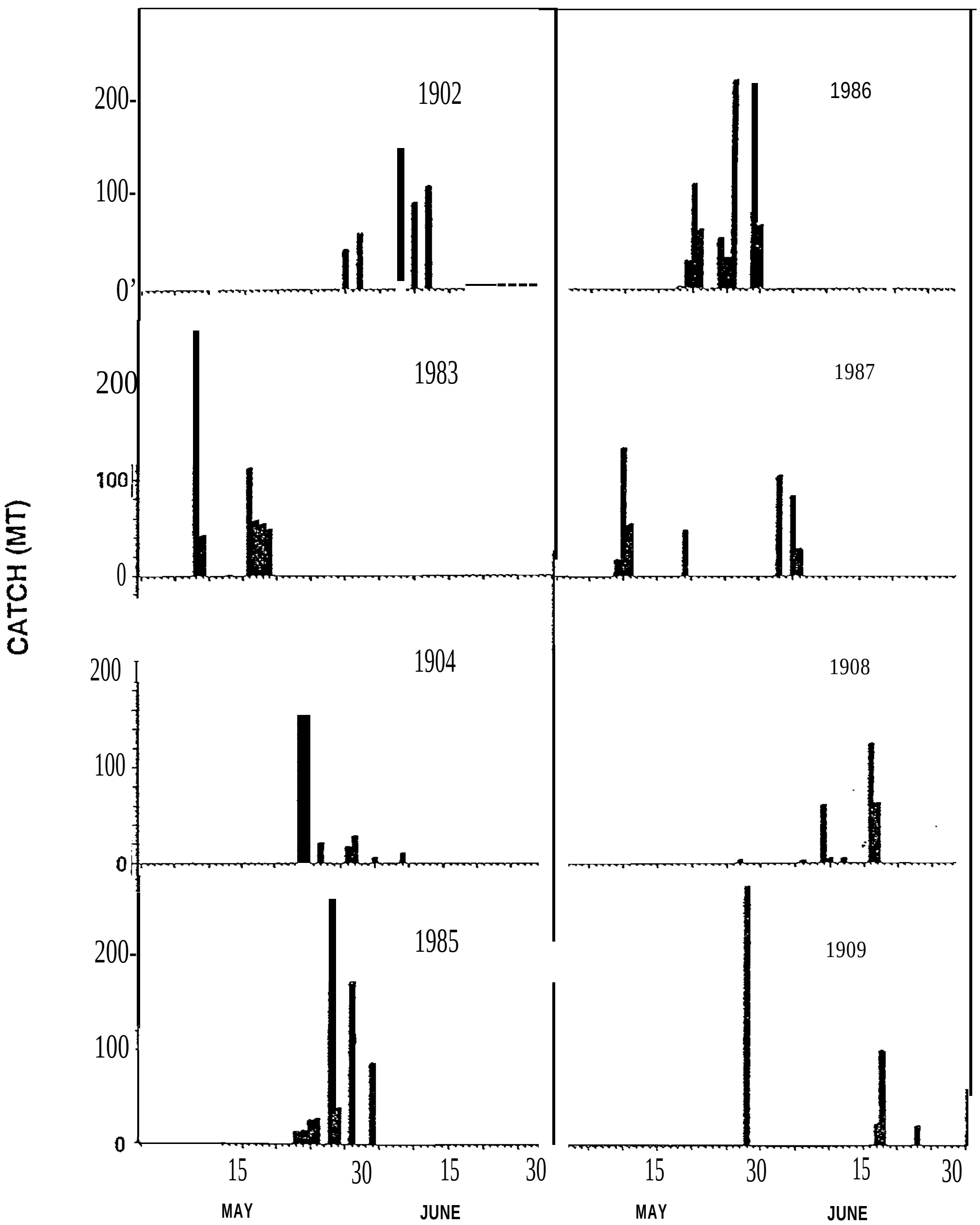


Fig. 4. Dates of herring harvest in Port Moller.

Table 3. Earliest dates of herring spawning in Port Moller based on commercial landings, percent roe yield of the catches, and estimated biomass of spawners from ADF&G's aerial surveys.

		Mean date of spawning		
Year	Spawning run	Commercial landings	Percent roe yield	Aerial surveys
1982	early			
	late	June 7		
1983	early	May 13		
	late			
1984	early	May 26		May 25
	late			June 4
1985	early	May 30		
	late			
1986	early	May 25		
	late			
1987	early	May 11	May 11	May 15
	late	June 3	June 4	June 2
1988	early	May 28	May 28	May 25
	late	June 14	June 17	June 4
1989.	early	May 29	May 29	May 29
	late	June 18	June 19	June 14

Notes:

1. Dashes indicate that data is not available.

MT of herring was observed by ADFG pilots near Bear River northeast of Port Moller. A 6 h opening of the fishery was declared and 284 MT were taken in upper Moller Bay. On May 30, peak biomasses of 1,016 and 748 MT were observed in Herendeen and Moller Bays, respectively, for a total spawning escapement of 1,764 MT. These fish must have spawned quickly and then left because only 7 MT were observed on May 31 and June 1. The sac-roe fishery remained closed until more herring moved into the area.

A spawning escapement of 1,764 MT is equivalent to 1.764×10^{11} newly-laid eggs, assuming a sex ratio of 1:1 and a relative fecundity of 200 eggs g-* of female body weight.

Two weeks later another group of spawners began to enter the estuary. From June 9 through 12 industry pilots reported small groups (180 to 270 MT) of herring entering Moller and Herendeen Bays. ADFG pilots observed 343, 154 and 332 MT of herring in Moller Bay on June 13, 15 and 16, respectively. The Port Moller district was opened to the fleet on June 16 and 167 MT were taken between June 16 and June 23. The fishery was closed for the year on July 15.

4.1.4 Age structure

The age distribution of Port Moller herring is characterized by strong year classes (Fig. 5). The fish that hatched in 1977 dominated the spawning population from 1981 to at least 1983. In 1981, as 4 yr olds, they comprised over 70% of the entire spawning population, and their presence was still marked by greater than usual percentages of 9 and 10 yr old fish in May 1986 and May-June 1987, respectively. Another strong year-class hatched in 1981 and entered the spawning population as 3 yr olds in 1984. It dominated the population from 1985 to 1987.

A second important feature of the age structure is that the modal age of fish that spawn in June is 1 to 2 yr lower than that of fish that spawned in May. This is most obvious in the age structure of the 1987 spawners. Apart from this difference, the May and June age distributions are similar, especially in the relative frequencies of the 8, 9 and 10 yr old age classes.

4.1.5 Size and growth

The only published data on the size and average growth rates of herring from Port Moller is the 1982 annual management report of ADFG's Kodiak office. This document shows that Port Moller herring range in length from 212 mm at age 3 yr to 301 mm at age 9+ yr:

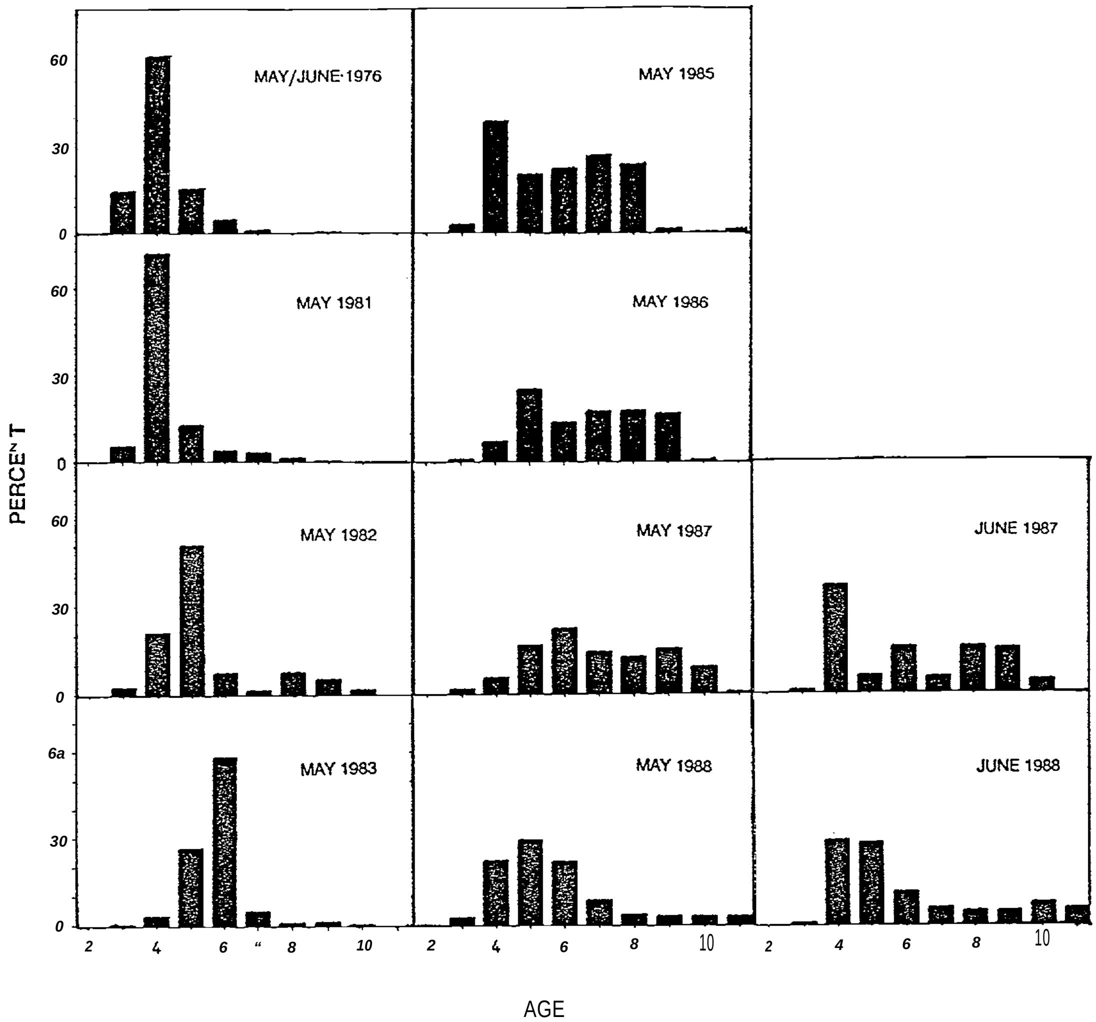


Fig. 5. Age structure of Port Moller herring.

Age (yr)	3	4	5	6	7	8	9	+
Mean length (mm)	212	242	260	266	275	292	301	

Avon Bertalanffy growth model (Ricker 1975) best described this data,

(17) $L_t = 328.36\{1 - \exp[-0.22(t + 1.85)]\}$

where L_t = mean length (mm) at age t (yr). These parameters are similar to those reported by Fried and Wespestad (1985) for herring from Togiak and Norton Sound.

There is no published weight-length data for Port Moller herring. Fried and Wespestad (1985) report that no geographic differences were found in the weight-length regressions between Togiak and Norton Sound herring, and so they used a single relationship,

(18) $W = 1.0X\ 10^{-6}\ L^{3.479}$

where W = total body weight (g) and L = length (mm).

4.1.6 Fecundity

There is no published information on the fecundity of herring from Port Moller, but there are two sets of fecundity measurements available for herring from the Bering Sea. Warner and Stafford (1979) reported 86 measurements of fecundity and length for herring collected from the Togiak district of the eastern Bering Sea in 1977; and in 1985 the Alaska Department of Fish and Game collected more Togiak herring for fecundity analysis (personal communication, K Rowell, ADFG, Division of Commercial Fisheries, 333 Raspberry Road, Anchorage, Alaska 99518). This second set of data has yet to be analysed, but fecundities of 19 of the 1985 fish were sent to me for my examination.

Covariance analysis showed that the slope of the regression of ln(egg number) on ln(length) of the Togiak herring was significantly ($P < 0.001$) lower for the fish collected in 1977 than for the fish collected in 1985, which means that the two data sets cannot be combined. Length-specific fecundity of Pacific herring is reported to decrease with increasing latitude (Nagasaki 1958, Paulson and Smith 1977, Hay 1985), and between-year differences in the fecundity-size relationship have been reported to be relatively minor in comparison, at least in herring from British Columbia (Hourston et al. 1981). Thus, the difference between the 1977 and 1985 data is most likely due to the use of different techniques of counting egg numbers. Fecundity of both sets of fish was measured with the gravimetric method, but Warner and Stafford (1979) dried the ovaries before weighing sub-samples of eggs whereas in 1985 ADFG personnel used the wet weights of the ovaries.

The relative fecundity (F,) of the Togiak herring was calculated in order to determine which of the two sets of data was most reliable. The weight of the fish caught in 1977 was estimated from their length using the weight-length regression for Togiak herring reported by Fried and Wespestad (1985) [equation (18)]

		Relative fecundity (g^{-1})		
Year	Area	mean	SD	n
1977	Togiak, Alaska	147.9	36.9	86
1985	Togiak, Alaska	205.0	30.5	19

F_r of the 1977 fish was highly significantly (t-test: $P < 0.001$) lower than that of the 1985 fish, and also highly significantly (t-test: $P < 0.001$) lower than F_r for herring from both British Columbia and California (Hay 1985)

		Relative fecundity (g^{-1})		
Year	Area	mean	SD	n
1974	North coast, B.C.	204.0	40.4	1715
1974	West coast, B.C.	217.1	34.2	855
1974	St of Georgia, B.C.	224.5	16.9	723
1980	North coast, B.C.	186.8	33.3	921
1980	West coast, B.C.	197.2	31.5	290
1980	St of Georgia, B.C.	205.2	53.5	431
1975	California	216.2	20.7	37

F_r of the 1985 Togiak herring was not significantly different from that of the B.C. or California herring (t-test: $P > 0.05$). Therefore, I conclude that the 1985 Togiak data is the only accurate fecundity data for herring of the eastern Bering Sea, and that Warner and Stafford (1979) underestimated the fecundity of the herring collected in 1977. Following Hay (1985), I assume that F_r of all Pacific herring, including the Port Moller fish, is approximately 200 g^{-1}.

4.2 Temperature and salinity

The temperature and salinity profiles of each plankton station are shown in Appendix D. Figs. 6 and 7 show the isopleths of temperature and salinity for Moller and Herendeen Bays, respectively. These plots were taken from a report prepared for Triton Environmental Consultants Ltd. by J. E. Edinger Associates, Ltd. (Edinger and Buchak 1989). These data indicate that most of the Port Moller complex except for Herendeen Bay follows the pattern seen in a typical estuary. The highest temperatures and lowest salinities are found at the head of Moller Bay where the water is shallow and diluted by freshwater inflow, and the lowest temperatures and highest salinities are found in the Bering Sea off Bear River. Between these areas (stations A to G) is a gradient of decreasing temperatures and increasing salinities.

Both temperature and salinity at the head of Moller Bay were highly variable. At station A salinity decreased from a mean of 23.22 ppt on June 13 to a mean of 4.28 ppt on June 14. This variability was due to changes in freshwater inflow, as is shown by the fact that variability decreased with increasing distance from the head of the Bay.

A lower gradient of temperature and salinity is shown by the stations in Herendeen Bay (O, N, M, L, K). Although temperatures were higher than those measured in the Bering Sea, they were generally lower than those measured in upper Moller Bay. This was due to the deep water at the head of Herendeen Bay.

4.3 Population dynamics of herring larvae

A total of 25 plankton samples were taken between June 11 and June 14, 1989, of which 22 contained at least 1 herring larva. A total of 11,314 herring larvae were sorted from these 22 samples, of which 1,594 had their lengths measured and the presence or absence of a yolk sac recorded.

4.3.1 Number of cohorts

The lengths of all herring larvae measured in this study are listed in Appendix E, and plotted in Fig. 8. The length frequency plots for the combined catches of June 11, 12 and 14 are not normally distributed, which indicates a mixture of cohorts. At least 2 cohorts of herring larvae were present: cohort 1 had lengths greater than about 11.0 mm, and cohort 2 had lengths ranging from 7.5 to 11.(I mm. Cohort 2 larvae were found in all of the 22 samples that contained herring larvae, but cohort 1 larvae were found in only 10 of the 22 samples.

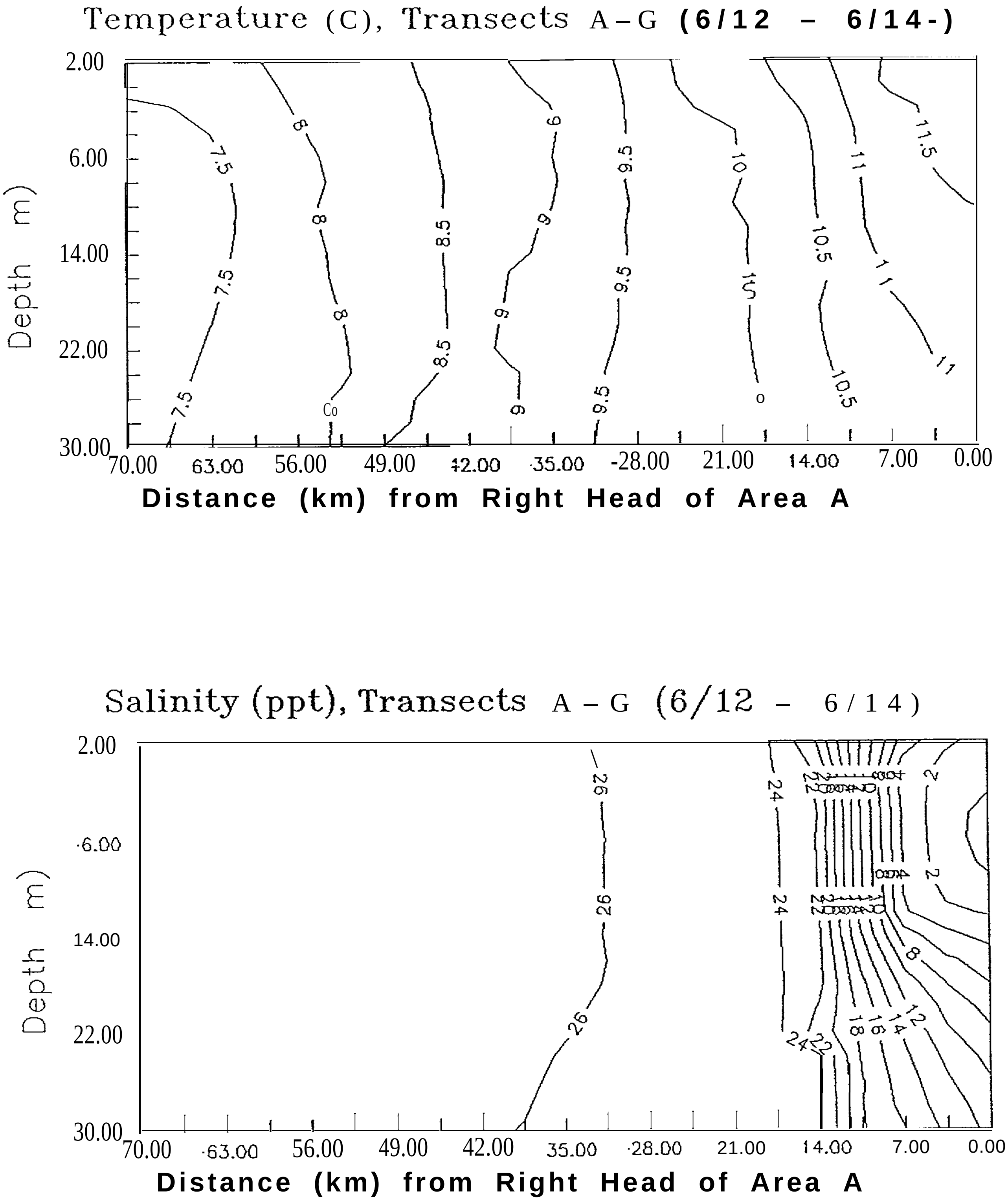
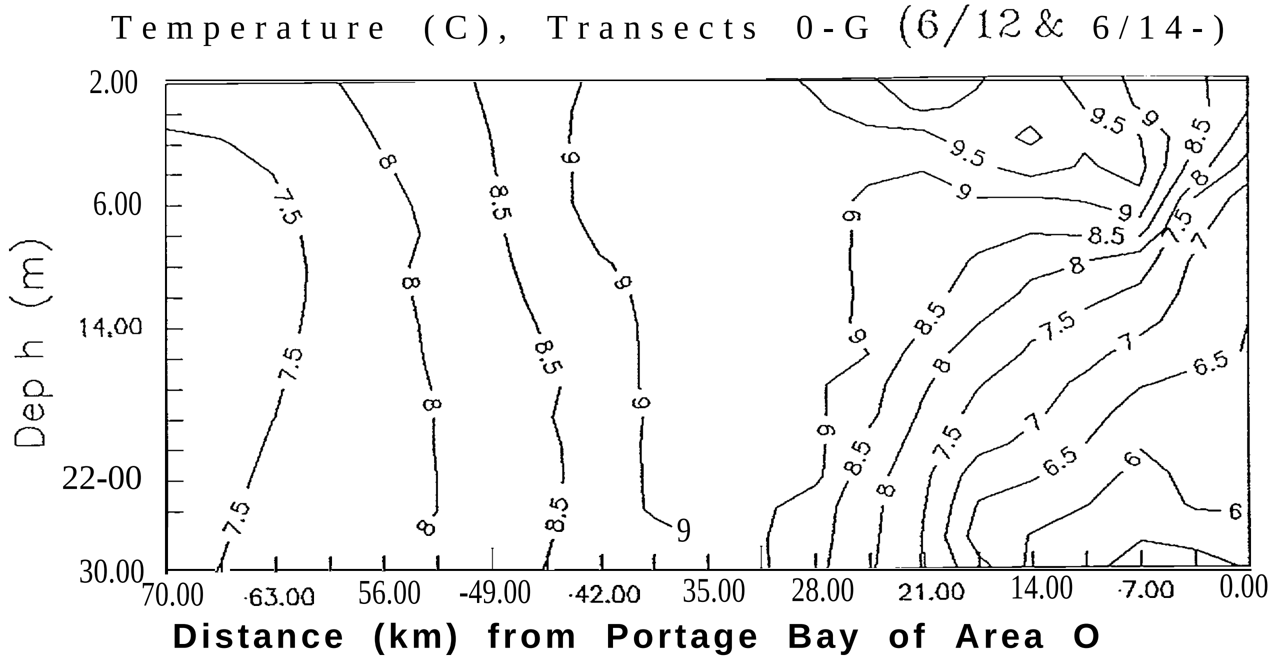


Fig. 6. Temperature and salinity isopleths of Moller Bay.



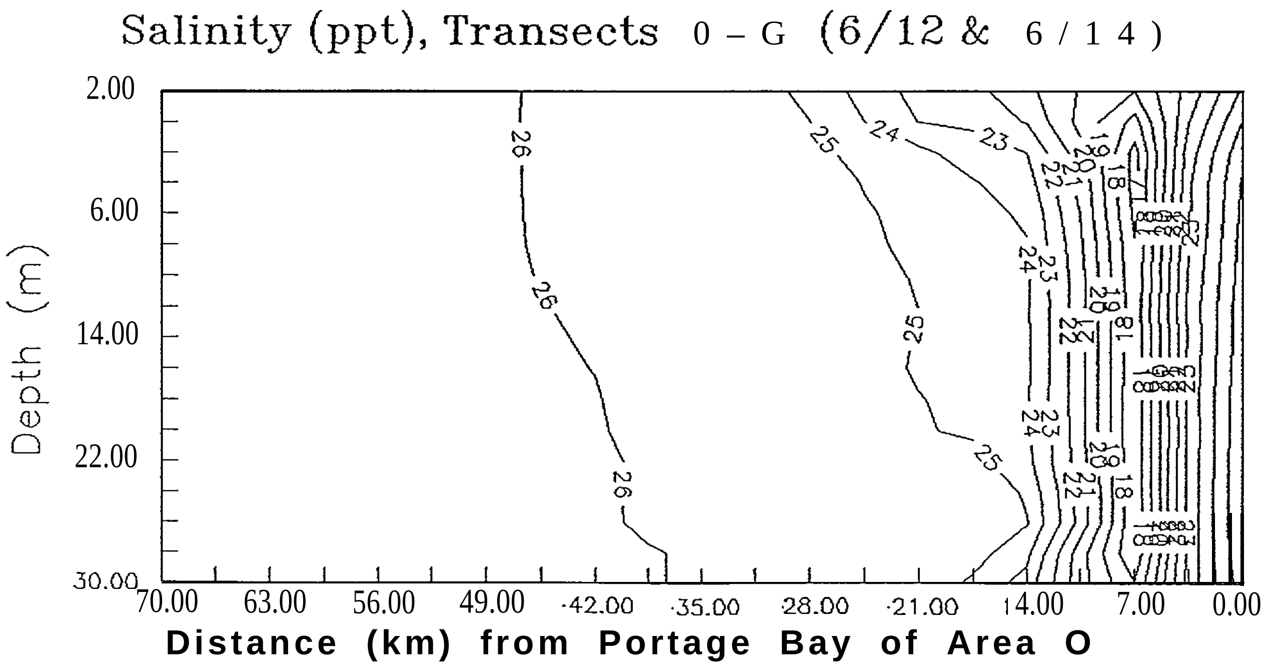


Fig. 7. Temperature and salinity isopleths of Herendeen Bay.

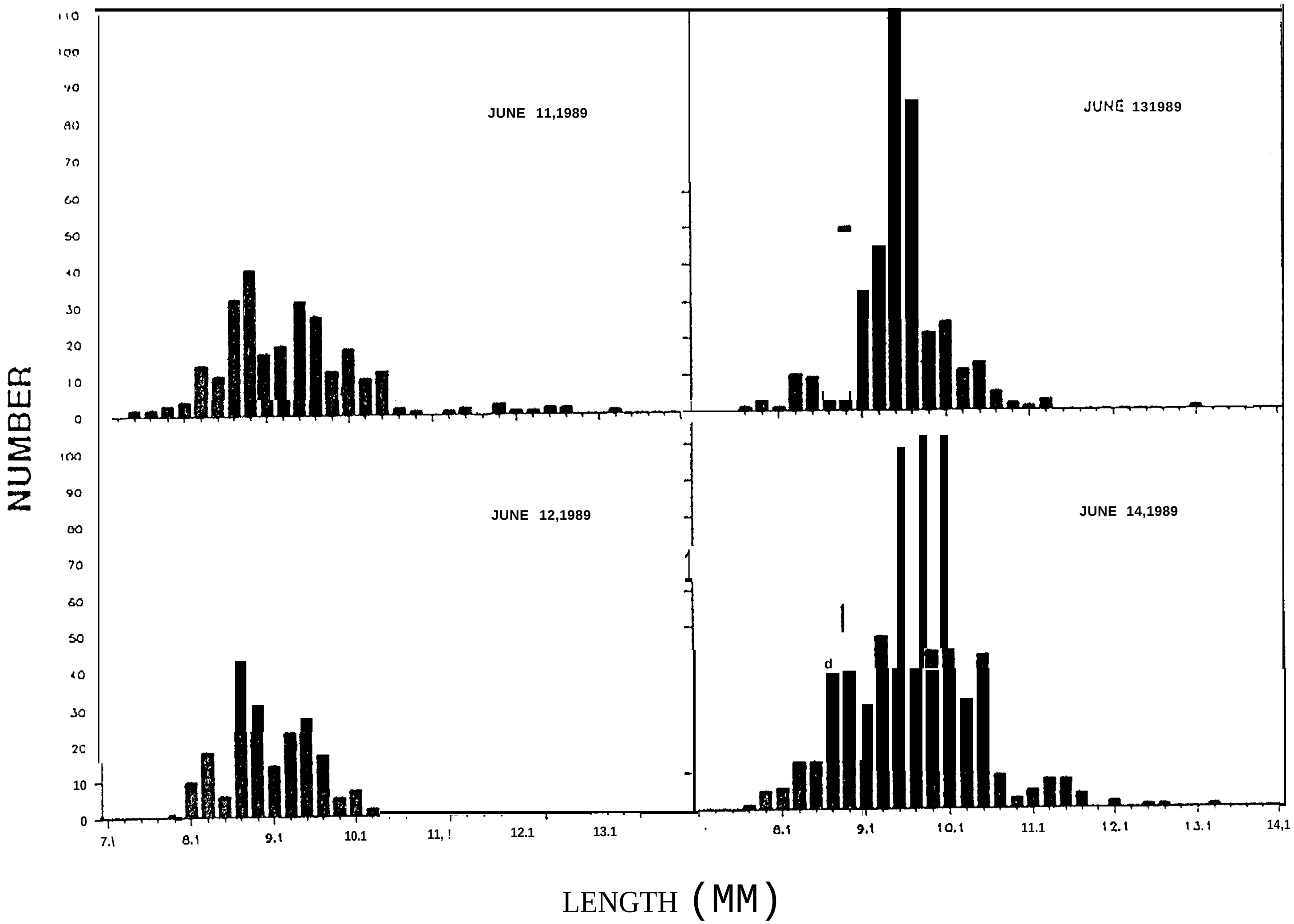


Fig. 8. Length frequencies of herring larvae.

The length frequency plots also show that cohort 2 appears to have 2 modes separated by about 0.8 mm: one at 8.7-8.9 mm, and a second at 9.5-9.7 mm. This observation suggests that cohort 2 may have been composed of 2 groups of larvae. Either *one* group hatched before the first, or the 2 groups hatched on the same date, but the larvae of the first mode grew at a slower rate than the larvae of the second mode.

This observation is supported by percent yolk sac data (Table 4), which shows that there were 2 centers of high percent yolk sac: one at station A in upper Moller Bay on June 11, and a second at stations K and M in upper Herendeen Bay on June 12. It is not likely that the centroid of cohort 2 was advected from one bay to the other in 1 d. Instead, this data suggests that there were 2 groups within cohort 2 one which hatched into upper Moller Bay, and a second which hatched into upper Herendeen Bay.

4.3.2 Age and growth

It was not possible to calculate initial ages of cohort 1 larvae using equation (5) because they had all exhausted their yolk, but ageing was possible for 19 of the 22 samples containing cohort 2 larvae because they contained at least 1 yolk sac larva. Table 4 shows that the percent yolk sacs for cohort 2 larvae ranged from 3 to 67%, and the ages ranged from 2.3 to 6.9 d.

Covariance analysis showed that the intercept of the regression of length on age was not significantly ($P > 0.05$) different between larvae from Moller and Herendeen Bays, but that the growth rate, G, of Moller Bay fish was significantly ($P = 0.0013$) higher than that of Herendeen Bay fish. Therefore, separate regressions were calculated for each group (Fig. 9)

Moller Bay and Bering Sea:

(19a) $L = 8.20 + 0.25t$
$r^2 = 0.53$, $n = 11$, $SE_b = 0.08$, $0.01 < P < 0.05$

Herendeen Bay:

(19b) $L = 8.47 + 0.12t$
$r^2 = 0.76$, $n = 6$, $SE_b = 0.03$,$0.01 < P < 0.05$

These growth equations were used to estimate the age of samples with no yolk sac larvae from their mean length.

Table 4. Mean lengths, percent yolk sacs, and age of herring larvae of cohort 2.

Site	Mean length (mm)				Percent yolk sacs				Age (d)			
	June 11	June 12	June 13	June 14	June 11	June 12	June 13	June 14	June 11	June 12	June 13	June 14
Upper Moller f3ay												
A	8.8		9.6	9.8	40		5	16	3.7		5.8	5.1
B				9-5				29				4.3
c			9.3	9.5			25	13			4.6	5.3
D	9.3		9.1	9.4	28		49	10	4.4		3.1	55
Lower Moller Bay												
E			9.3				13				5.3	
J				9.4				0				
Bering sea												
F	9.8				12				5.6			
G												
H		10.2				0						
I												
Herendeen Bay												
K		8.8		9.1		67		4		2.3		6.8
L				9.4				0				
M		8.7		9.3		66		13		2.4		6.2
N				95				3				6.9
O		9.1				10				6.4		

Note:

1. Age = 40.86*T^-0.8437*(1-f), where f = fraction of yolk-sac larvae.
2. Dashes indicate age was not calculated because f = O.

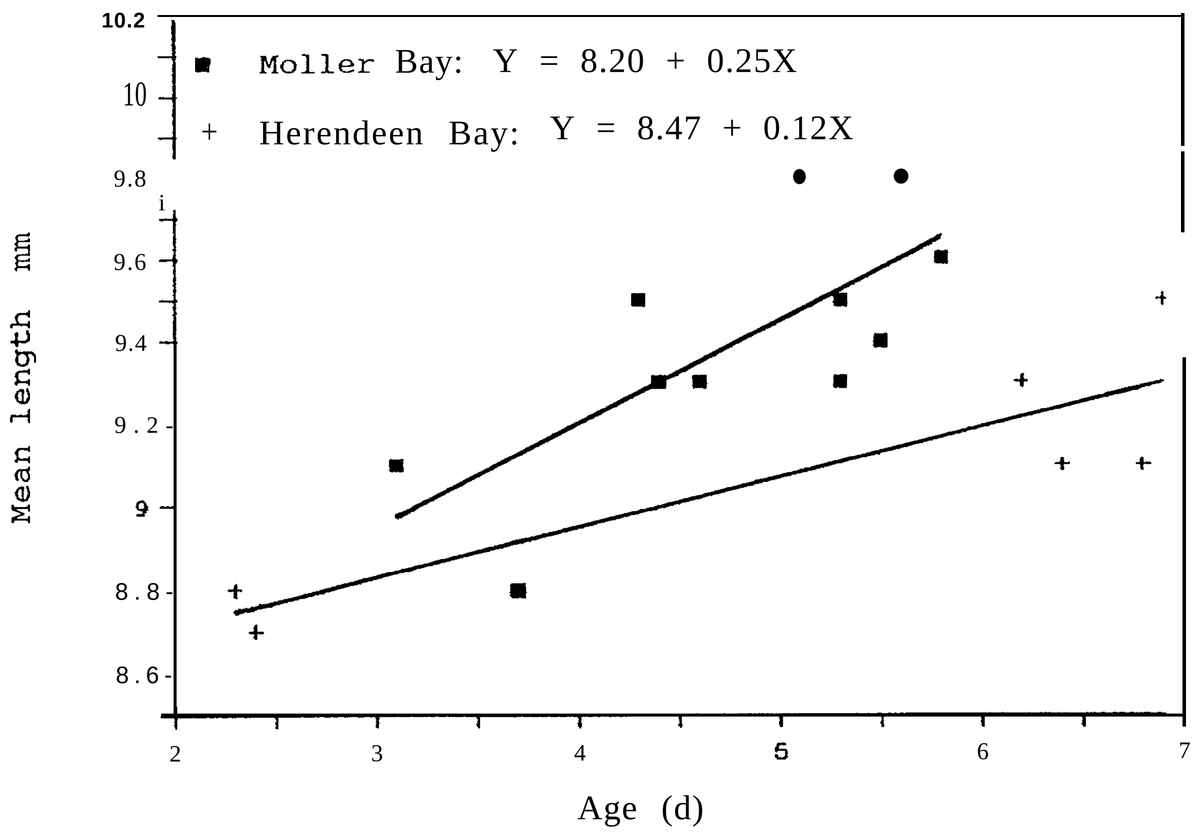


Fig. 9. Growth of herring larvae.

The growth of herring larvae in Port Moller are within the range reported for other populations of Pacific and Atlantic herring larvae (McGurk 1984, 1989b). The difference in growth rate between fish in Moller Bay and fish in Herendeen Bay is most likely a response to higher water temperatures in Moller Bay than Herendeen Bay.

4.3.3 Timing of cohorts

The hatching dates of cohorts 1 and 2 were back-calculated from their mean lengths on June 12 to have been May 29 and June 10, respectively (Table 5). The hatching date of cohort 2 was also estimated to be June 11 by forward-calculation from the approximate date of spawning on May 29 as derived from aerial surveys and the records of landings from the commercial fishery. Therefore, the interval between the hatching dates was approximately 11-12 d.

The spawning dates of cohorts 1 and 2 were further back-calculated from the hatching dates to be May 15 and May 27, respectively. Combined with a range of spawning dates for cohort 3 of June 14 to 18, based on commercial catches and aerial survey data, this gives an estimate of the duration of the interval between spawning dates that range from 12 to 21 d.

4.3.4 Dispersal and mortality

The greatest densities of herring larvae in both cohorts 1 and 2 were measured at station A at the head of Moller Bay (Table 6). Density decreased with increasing distance from this site, declining to a non-detectable level at stations G and I in the Bering Sea. The exceptions to this rule were the densities of cohort 1 and 2 larvae in Herendeen Bay; a consistent increase in density was measured at stations M and O near the head of the Bay.

This pattern of distribution supports the conclusions concerning the double origin of cohort 2 that were suggested by the bimodal length frequencies, by the two centers of high percent yolk sacs, and by the lower growth rates of larvae in Herendeen Bay.

The densities of cohort 1 herring larvae in Moller Bay and the Bering Sea were best fit by a diffusion model with no mortality term. The parameter values of this model are shown in Table 7. The densities of cohort 1 herring larvae in Herendeen Bay could not be fit by any version of equation (16) because there were only 2 non-zero counts. Therefore, in calculations of spawning stock biomass, cohort 1 larvae were assumed to be distributed at a geometric mean density of 0.063 m^{-3} at all stations in Herendeen Bay. The densities of cohort 2 herring larvae in Moller Bay and the Bering Sea were best fit with equation (16b), but the densities of cohort 2 larvae in Herendeen Bay were

Table 5. Dates of spawning and hatching for herring of Port Moller.

Cohort	Date of spawning: catches plus aerial surveys	back-calculation from hatch date	duration of interval between cohorts (d)	forward-calculation from spawning dale	Dale of hatching: back-calculation from length-at-date	duration of interval between cohorts (d)
1		May 1S			May 29	
2	May 29	May 27	12-14	June 11	June 10	11-12
3	June 14-18		15-21			

Notes:

1. Dashes indicate no data available.
2 Dates of spawning for cohorts 1 and 2 were back-calculated from the hatch dates using equation (8) and assuming a mean surface temperature of 9.SdegC. See Note 4 for explanation of calculation of hatching date-s.
3. Date of hatching of cohort 2 was forward-calculated from the spawning date estimated from aerial surveys and fishery catches by using equation (9) and assuming an average surface water temperature of 9.64degC for Moller and Herendeen Bays.
4. Dates of hatching of cohorts 1 and 2 were back-calculated from mean lengths of 12.0 and 9.2 mm, respectively, on June 12 by using equation (7) and assuming a growth rate of 0.2.5 mm d--l and a mean length at hatch of 8.4 mm.

Table 6. Number and density of herring larvac in Port Mollcr, 1989.

Date	Site code	Time	Sample number	Volume filtered by net (m^3)	Cohort 1 number	Cohort 1 measured density (m^-3)	Cohort 1 corrected density (m '-3)	Cohort 2 number	Cohort 2 measured density (m-3)	Cohort 2 corrected density (m-3)	Total number	Total measured density (mu-3)
Upper Moller Bay												
11-Jun-89	A	1200	3	133.181	81	0.608	2.162	813	6.104	8.902	894	6.713
11-Jun-89	D	0915	1	88.610	4	0.045	0.156	59	0.666	1.142	63	0.711
11-Jun-89	D	0945	2	212309	1	0.00.5	0.012	132	0.622	1.038	133	0.626
13-Jun-89	A	1515	13	208.96s	32	0.153	0.694	3133	14.993	27.134	3165	15.146
13-Jun-89	C	142s	12	249.464	0	0.000	0.000	1640	6574	10.972	1640	6-574
13-Jun-89	C	1625	14	187.584	0	0.000	0.000	875	4.665	7.578	875	4.665
13-Jun-89	D	0850	11	217.141	0	0.000	0.000	491	2.261	3.576	491	2.261
14-Jun-89	A	1630	22	113319	0	0.000	0.000	1652	14578	27.848	1652	14577?3
14-Jun-89	B	1705	23	162.419	10	0.062	0.213	1042	6.416	11301	10s2	6.477
14-Jun-89	C	1745	24	190.745	1	0.005	0.018	97	0509	0.8%	98	0514
14-Jun-89	D	1825	25	177.934	2	0.011	0.045	244	1371	2351	246	1.383
Lower Moller Bay												
13-Jun-89	E	1710	17	200.881	0	0.000	0.000	68	0.339	0565	68	0.339
14-Jun-89	J	1350	16	117.924	1	0.008	0.027	14	0.119	0.204	15	0.127
Bering Sea												
11-Jun-89	F	2543	4	124.853	0	0.000	0.000	8	0.064	0.122	8	0.064
12-Jun-89	G	1110	7	259.873	0	0.000	0.030	0	0.000	0.000	0	0.000
12-Jun-89	H	0915	5	151599	0	0.000	0.000	1	0.007	0.014	1	0.007
12-Jun-89	I	0955	6	229.480	0	0.000	0.000	0	0.000	0.000	0	0.000
14-Jun-89	F	0800	15	191.611	0	0.000	0.Coo	0	0.000	0.000	0	0.000
Herendeen Bay												
12-Jun-89	K	125s	8	153.803	0	0.000	0.000	3	0.020	0.028	3	0.020
12-Jun-89	M	1600	10	197.766	0	0.000	0.000	225	1.138	1.615	225	1.138
12-Jun-89	O	1440	9	220.743	0	0.000	0.000	200	0.906	1.433	200	0.906
14-Jun-89	K	1300	21	260.937	2	0.008	0.030	25	0.096	0.151	27	0.103
14-Jun-89	L	1140	20	166.415	0	0.000	0.000	21	0.126	0.216	21	0.126
14-Jun-89	M	1035	19	209.269	8	0.038	0.132	274	1309	2.185	282	1348
14-Jun-89	N	0915	18	261.454	0	0.000	0.030	155	0593	1.044	155	0593
			TOTAL		142			11172			11314	
			MEAN	187.531	6	0.038	0.140	447	2539	4.413	453	2577
			SD	48363	17	0.123	0.445	744	4.243	7.752	751	4.284
			N	2 . s	2 5	25	25	25	25	25	25	25

Note-s
1. Corrected density = measured density*0.1355*exp(0.270 *L), where L= mean length.

Table 7. Parameter values (+ 1SE) of diffusion-mortality models.

		Cohort 1		Cohort 2		
				Moller		
				constant	Pareto	
Parameter	Units	Moller	Herendeen	mortality	mortality	Herendeen
ln(C/4πHK)	d	2.1126		7.1880	8.7716	2.1534
		(0.7947)		(1.02s9)	(1.6766)	(02795)
K	m^2 d--l	5.37%x1O"6	-	1.3608X1O"7	1.3265X1O"7	1.2504X1O'7
		(1.9965x10 6)		(0.1%8x10 7)	(O.18O6X1O"7)	(O.1677X1O"7)
Z	d--l			0.5279		
				(0.2085)		
β					2.6218	
					(0.7753	
n		8	2	15	15	7
r"2		055		0.86	0.87	0.92
radj"2		0.47		0.83	0.84	0.92
P-		0.036		<0.0001	<0.0001	0.0007

Notes:

1. SE = standard error; n = sample size;
   radj^2 = 1- (n/n - i)(1 - r-2), where i = number of parameters;
   P = statistical probability of the fit of the model.
2. Dashes indicate the parameter or model was not significan(P >0.05).

best fit with a model with no mortality term. A model with a constant rate of mortality [equation (16a)] explained 1% less of the variance in the densities of cohort 2 larvae of Moller Bay than equation (16b). The residuals of these models were not correlated with t, lnt, x, lnx, Julian date, or time of day at which the tow was taken.

The coefficients of diffusion of cohort 2 larvae were not significantly different (t-test: $P > 0.05$) between those captured in Moller Bay and those captured in Herendeen Bay, but they were 2.3 to 2.5 times higher than the K of the cohort 1 larvae, a difference that is very significant (t-test: $0.001 < P < 0.01$). The lower K for cohort 1 larvae may have been due to the fact that these fish were 9 d older than the cohort 2 fish. Herring larvae cease dispersal as they age and begin to school.

Only one estimate of mortality was obtained, from cohort 2 larvae in Moller Bay; β was significantly higher than 1.0 (t-test: $P < 0.01$) and Z was significantly higher than 0.0 (t-test: $0.02 < P < 0.05$).

In order to determine if the unexplained variance in larval density was caused by violations of the two major assumptions of the models: constant or Pareto-type mortality and Fickian diffusion, the diffusion term and the mortality term on the right-hand side of equation (16b) were moved to the left-hand side to produce diffusion-corrected and mortality-corrected densities. These corrected densities were then plotted against t and X^2t^{-1}, respectively, and examined for any residual pattern that would indicate a choice of an inappropriate model. Figs. 10 and 11 show no evidence of residual pattern, indicating that that the assumptions of Pareto-type mortality and Fickian diffusion are correct.

However, the plot of diffusion-corrected densities against age for cohort 2 larvae of Moller Bay shows that a constant mortality rate could be substituted for a Pareto-type mortality rate with little decrease in predictive ability of the model. Although this observation has little consequence for the choice of the best predictive model of densities of cohort 2 larvae in Moller Bay, it has important consequences for the back-calculation of the density of newly-hatched larvae because the Pareto-type model predicts much higher densities at t = O for cohort 2 than the constant-mortality model. This topic is examined in greater detail in section 4.4.1.

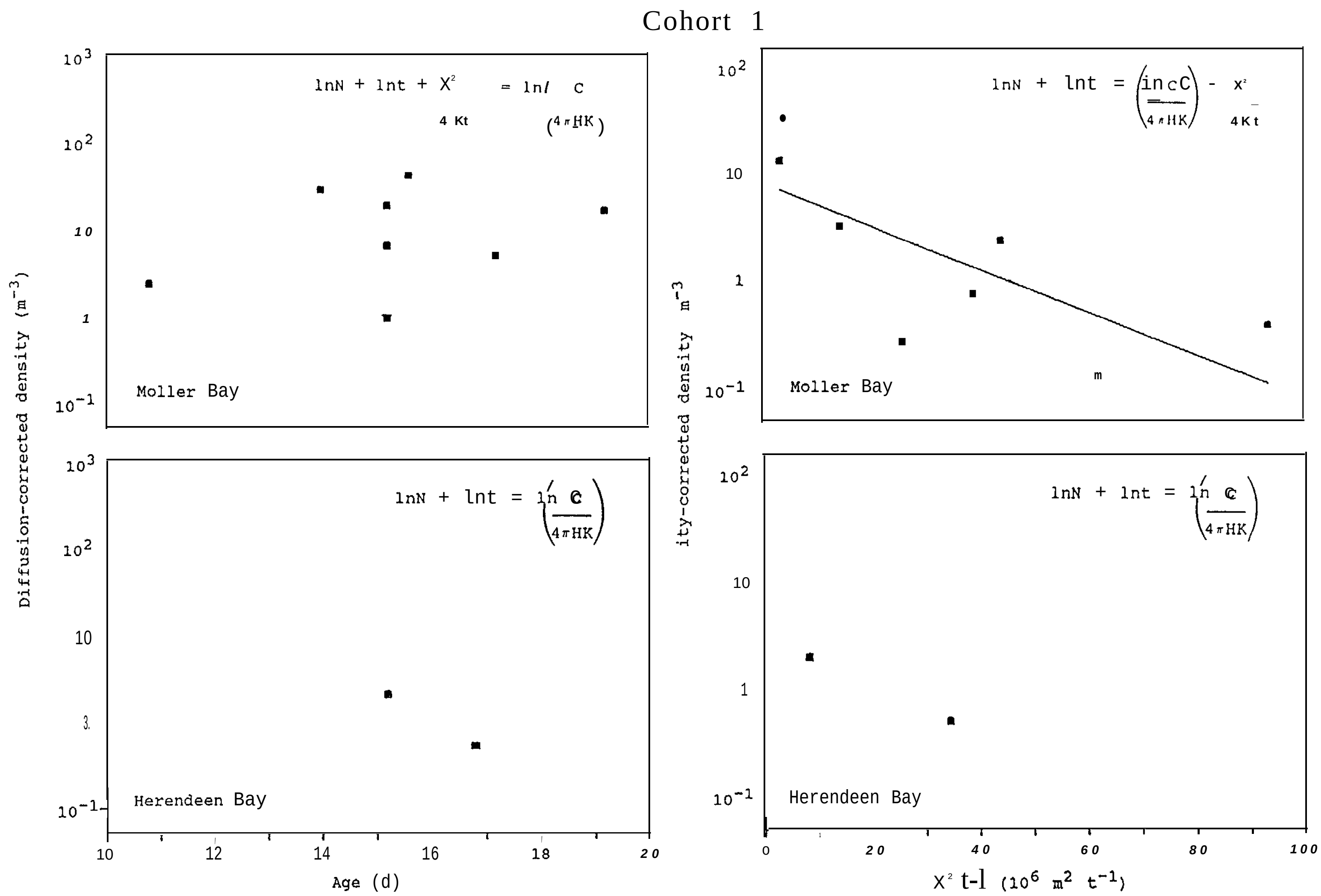


Fig. 10. Diffusion- and mortality-corrected densities of cohort 1 larvae.

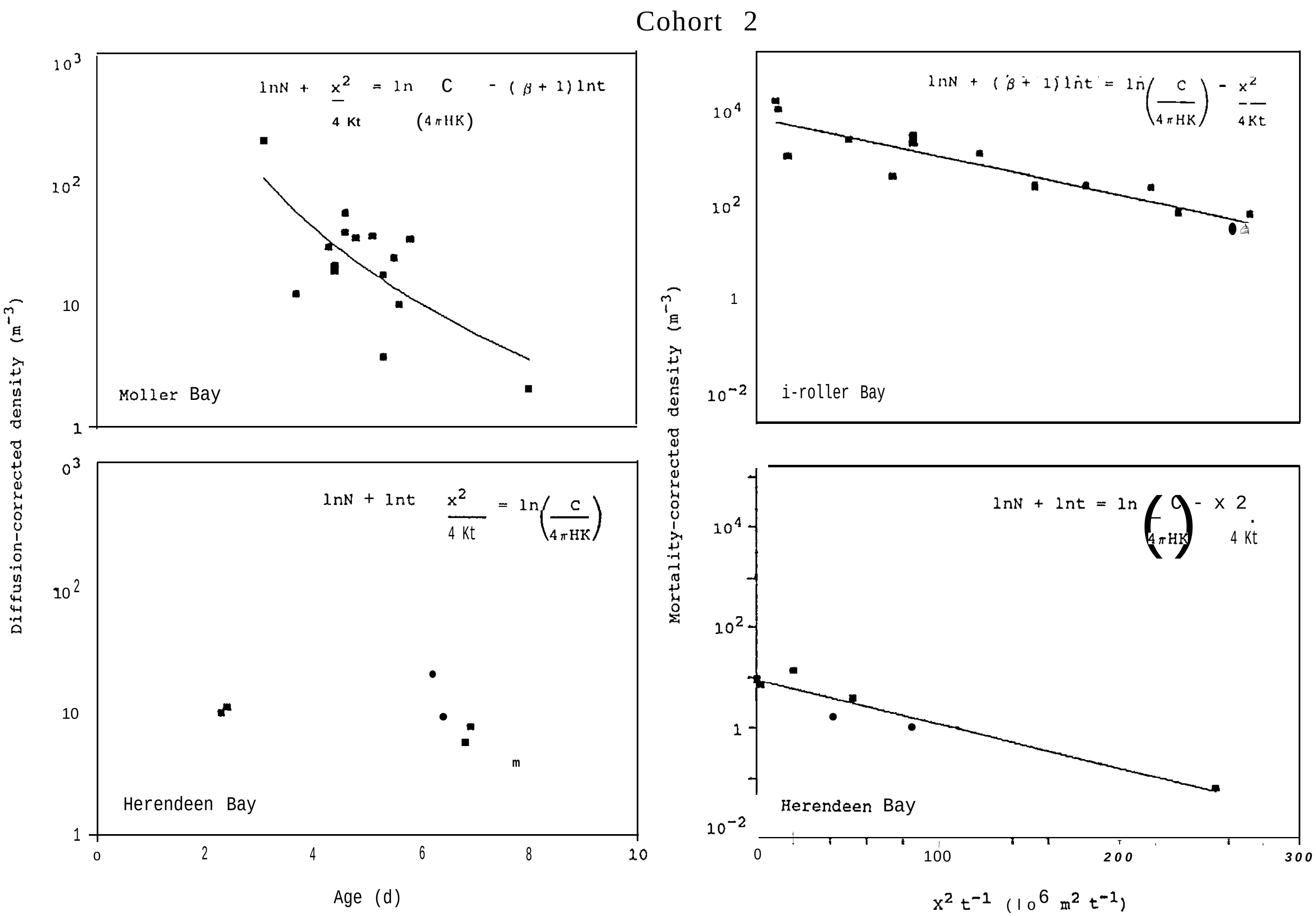


Fig. 11. Diffusion- and mortality-corrected densities of cohort 2 larvae.

4.4 Spawning biomass

4.4.1 Parameter estimates

Survival during the egg stage (s_1)

In the absence of any information on s_1 for the herring eggs of Port Moller, we must choose a range of values from those reported in the scientific literature. There is little consensus on the magnitude of losses of herring eggs due to exposure and predation. Early research in British Columbia on the effects of bird predation (Outram 1958), wave action (Taylor 1964), and exposure and water depth (Taylor 1971, Jones 1972) on the survival of naturally-spawned Pacific herring eggs produced loss rates ranging from 25% to 55%. These are equivalent to Z_e = 0.017 to 0.047 d^{-1}, assuming an average egg incubation time of 17 d at an average water temperature of 8°C (Alderdice and Velsen 1971). However, Haegele et al. (1981) argued that the total loss from exposure and bird predation is closer to 1096 or less (or Z_e = 0.006 d^{-1} or less) in southern British Columbia (B. C.) because most of the eggs in that region are laid in subtidal habitat and so only a small fraction of the total number of eggs is exposed to dessication, wave action or predatory birds during each tidal cycle. Following Haegele et al. (1981), the current practice of herring biologists in B.C. is to assume that negligible mortality occurrs during the first week after spawning (Schweigert and Stocker 1988). This argument assumes that predation from bottom-feeding fish or invertebrates is negligible, an assumption which is questionable, especially since there is no published information on losses of herring eggs in subtidal habitat in British Columbia. Some experienced SCUBA divers report observing few potential predators on herring spawn in Prince William Sound, Alaska, (personal communication, E. Biggs, Division of Commercial Fisheries, ADFG, P.O. Box 669, Cordova, Alaska 99574-0669), but others report observing large numbers of flatfish on herring beds in Bristol Bay (personal communication, M. Stekoll, University of Alaska-Southeast, Juneau, Alaska 99801).

The current practice of ADFG herring biologists in southeast Alaska is to assume that 25% of the eggs are lost to exposure and predation unless extraordinarily high concentrations of birds are observed feeding on the eggs, in which case a predation mortality of 50% is assumed (Blankenbeckler 1987). If the average incubation period herring eggs in southeast Alaska is approximately 21 d, then this is equivalent to assuming a daily predation mortality of 0.014 to 0.033 d-l.

A wide range of estimates of egg mortality due to predation has also been reported for Atlantic herring. Tibbo et al. (1963) reported that densities of winter flounder (Pleuronectes americanus) greater than 1 m^{-2} were observed with SCUBA techniques on egg beds near Blanchard Point in Chaleur Bay, New Brunswick. Their stomachs contained nothing but herring eggs. The mortality of eggs due to this single species of fish was calculated from their densities and from average number of eggs in their stomachs to be at least 7910 over the spawning/incubation period of 50 d or at least 0.0015 d^{-1}. This is almost certainly an underestimate of total predation mortality because large numbers of other species of fish were also observed to be feeding on herring eggs.

Caddy and Iles (1973) reported a similar magnitude of total predation on herring eggs laid on Georges Bank. They observed from a submersible that the eggs had attracted a feeding community of fish and invertebrates, and calculated a mortality rate of 8% for the entire incubation period up to about 1 to 2 d before hatching from the number and the size of holes that predators had made in the egg bed. If we assume a spawning/incubation period of approximately 50 d (Tibbo et al. 1963), then this is equivalent to a Z_e of 0.0017 d^{-1}.

Dragesund and Nakken (1973) estimated that about 40% of the potential herring egg production of the Ona-Grip area off the northern coast of Norway was consumed by haddock (Melanogrammus aeglefinus) and saithe (Pollachius virens). They based this estimate on echo-sounding surveys of fish abundance over the egg beds, and on trawl surveys of the fish community. Eighty percent of the haddock and 15% of the saithe caught by the trawls were found to have herring eggs in their stomachs. If the incubation period of the eggs is approximately 25 d as it is in Lindaaspollene, western Norway (Johannessen 1986), then Z_e = 0.020 d-'.

Johannessen (1986) reported that the rates of egg loss from herring egg beds in a fjord on the western coast of Norway ranged from 20 to 60% (mean = 34%) during the first 2 wk after spawning, for a range of Z_e of 0.009 to 0.037 d^{-1} (mean = 0.017 d^{-1}). The loss rates were assumed to result entirely from predation by bottom-feeding invertebrates and fish and by diving ducks. Losses from wave action and strong currents were assumed to be negligible.

Predation mortality of demersal eggs of fish species other than herring has also been measured. Frank and Leggett (1984) reported that mortality of capelin (Mallotus villosus) eggs deposited in the beach of Conception Bay, Newfoundland, from predation by winter flounder (Pseudopleuronectes americanus) ranged from 1.9 to 5.0% (mean = 3.0%, n = 3) over an incubation period of 40 d, which is equivalent to a Z_e of 0.0005 to 0.0013 d-l (mean = 0.0008 d-l).

In summary, Pacific herring eggs laid in the subtidal zone may have a negligible risk of death from exposure and bird predation, but they almost certainly have a significant risk of death from predation by bottom-feeding fish and invertebrates. Almost all of the herring eggs laid in Port Moller are deposited in subtidal habitat. The range of Z_e of demersal fish eggs that has actually been measured is 0.0008 to 0.017 d^{-1} (Tibbo et al. 1963, Caddy and Iles 1973, Dragesund and Nakken 1973, Frank and Leggett 1984, Johannessen 1986). Therefore, since the egg incubation period in Moller Bay in early June 1989 was 100%/7.02% d^{-1} or 14.2 d, s_1 has an expected range of 0.79 to 0.99.

Fraction of eggs that hatch (s_2)

Alderdice and Velsen (1971) reported an equation that predicts the percent hatch of Pacific herring eggs from the temperature and salinity of their incubation water. Ifthe average temperature (9.89°C) and salinity (20.62 ppt) of the surface water of upper Moller Bay measured over the period June 11 to 14 was similar to the temperatures and salinities that the eggs encountered during their incubation, then their equation predicts a total hatch of 93.7%. This is the maximum percent hatch that could possibly have occurred because Alderdice and Velsen (1971) incubated their eggs under ideal conditions; only one layer of eggs was spawned and this layer was continually perfused with oxygenated seawater. Natural spawns usually consist of several layers of eggs and most studies on this subject have shown that multiple egg layers leads to restriction of the flow of oxygen to eggs in the inner layers and increased mortality of those eggs due to asphyxiation (Taylor 1971, Galkina 1971, Johannessen 1986). Therefore, in order to obtain a realistic value for s_2 we must refer to those reports which have measured the percent hatch of natural herring spawn.

It is generally concluded from the appearance of natural herring spawn that egg survival is high during incubation. Baxter (1971) and Hempel and Hempel (1971) reported that an average of 95.8'% and 96.1 to 94.3% of North Sea and Clyde Sea Atlantic herring eggs, respectively, were alive. Haegele et al. (1981) reported that they have rarely ever seen natural Pacific herring spawn from British Columbia which contained less than 90% live eggs. Johannessen (1986) reported similar results for Atlantic herring spawn from Lindaaspollene in western Norway.

These high survival rates do not persist through the hatching period either because the appearance of eggs is a poor index of their actual viability or because the act of hatching is so stressful that it leads to substantial mortality. Hourston et al. (1984) measured the percent total hatch and percent viable hatch of 50 batches of Pacific herring eggs spawned onto 14 different species of vegetation at 5 different spawning intensities. They reported that percent hatch was highly variable ranging from 16 to 100% and that it tended to decrease as spawning intensity increased. The intensity at which percent hatching fell off abruptly varied with the substrate tested, but it was generally low (mean = 30%, SD = 19, n = 21) for ail cases of heavy intensity, arbitrarily defined by Hourston et al. (1984) as greater than 250 eggs per linear in of eelgrass (98 eggs cm^{-1}) or greater than 500 eggs in^{-2} of kelp (775,194 eggs m^{-2}). The mean percent hatch for all cases was 54% (SD = 28, n = 50), and the mean for all cases of very light, light and medium egg intensity was 71% (SD = 19, n = 29).

Similar results were reported by Johannessen (1986) for natural Atlantic herring spawn that had been laid in Lindaspollene, western Norway. Percent hatching of 22 samples of spawn ranged from 17.2 to 84.4% with mean percent hatch decreasing from a maximum of 50.5% (n = 13) for light egg densities (<250,000 eggs m^{-2}) to 27.7% (n = 3) for heavy egg densities (500,000 to 1 million eggs m^{-2}). The mean percent hatch for all samples was 42.8%.

In the absence of any data on the density of herring spawn in Port Moller, the average density recorded for other stocks of herring must be used to guide the choice of an appropriate hatching success. The largest set of data on Pacific herring spawn intensity is a 30 yr long time series that has been collected by herring biologists in British Columbia (Hay 1985, Hay and Kronlund 1987). In general, the density of Pacific herring eggs laid in southern British Columbia ranges between 200,000 and 1 million eggs m^{-2} and rarely exceeds 4 million eggs m^{-2}. Similar densities are found among other Pacific and Atlantic herring stocks, although densities as high as 6 million m^{-2} have occasionally been recorded. Thus, s_2 is assigned a range of values from 0.30 to 0.71.

<u>Fraction of newly-hatched larvae that are viable</u> (s_3)

Hourston et al. (1984) defined viability of newly-hatched Pacific herring larvae as the absence of a bent body axis or retarded or abnormal development. Presumably, larvae defined as non-viable would not survive long enough to enter the population of feeding larvae. Indeed, no deformed larvae were ever observed in the samples taken from Port Moller. Hourston et al. (1984) reported that viability was usually over 80% and that it was not related to type of substrate or to spawning intensity. Therefore, a single mean percent viability was calculated, 83% (SD = 15, n = 50), and s_3 was assigned a value of 0.83.

If one assumes that s_1 = 0.79 to 0.99, S_2 = 0.30 to 0.71, and s_3 = 0.83, then 20 to 58% of the herring eggs laid in Port Moller are expected to hatch into viable larvae.

Relative fecundity (F,)

Following the arguments presented in section 4.1.6, F_r of Port Moller herring was assumed to be 200 eggs g-*.

Larval Mortality (2/ β)

The mortality rate measured from cohort 2 herring larvae in Moller Bay was assumed to apply to the larvae of both cohorts 1 and 2 in both Moller and Herendeen Bays. This estimate of mortality was one of the few parameters that was measured directly from the larvae of Port Moller, and it was calculated using a method that removed bias due to transport of the larvae out of the sampling area. However, some uncertainty exists concerning the correct way in which to extrapolate from a mortality rate measured at an average age of 5 d to an average age of O d or 14 d. Was the mortality rate constant with age? or did it decrease with age as is suggested by the slightly better fit of equation (16b) than equation (16a) to the density data of cohort 2 larvae in Moller Bay? A comparison of Z from Moller Bay with estimates of Z from the published literature

Z (d^{-1})	Age (d)	Location	Author
0.25	1-23	Barkley Sound, B.C.	Stevenson (1962)
0.40	1-27	Queen Cove, B.C.	Stevenson (1962)
0.09	1-48	Akkeshi Bay, Japan	Iizuka (1966)
0.12	1-30	Akkeshi Bay, Japan	Iizuka (1966)
0.02	5-55	Bamfield Inlet, B.C.	McGurk (1989a)
0.16	1-37	Bamfield Inlet, B.C.	McGurk (1989a)
0.53	3-8	Moller Bay, Alaska	this study

shows that the Z from Port Moller is the highest ever measured for Pacific herring larvae, but that it is also an estimate for the shortest and earliest age span. This suggests that one explanation for the high Z of Port Moller larvae is that it was measured for relatively young larvae, and that mortality of Pacific herring larvae may decrease with age according to some Pareto-type function. This argument is supported by Hewitt et al.'s (1985) report that mortality of young jack mackerel, Trachurus symmetricus, larvae decreased exponentially with age from rates as high as 0.9 d^{-1} for 1 d old fish, and by McGurk's (1986) suggestion that exponential declines in mortality rate with age may occur in pelagic eggs and very young larvae of many species of marine fish due to predation on patches of eggs and newly-hatched larvae.

However, this data must be interpreted with caution because of the many factors involved in their estimation. Also, as will be shown in section 4.4.2 below, the use of Pareto-type mortality to back-calculate the number of newly-hatched herring larvae in Port Moller leads to predictions of spawning biomass of cohort 2 that are much too high to be accepted. Therefore, in this study stock biomass was back-calculated using both Z and β, and the mortality function that predicted the most reasonable stock biomass was accepted as the best predictor of mortality in the immediate post-hatching ages.

4.4.2 Estimates of spawning biomass

Table 8 shows an example of the calculations used to back-calculate spawning biomass from density of larvae in Port Moller. Table 9 shows the biomasses of cohort 1 and 2 back-calculated under the assumptions of constant mortality and Pareto-type mortality, and for the two extremes of the range of likely values of s_1 and s_2. Spawning biomass of cohort 1 was calculated to range from 5,101 to 26,214 MT. Spawning biomass of cohort 2 ranged from 1,788 to 30,791 MT.

The fact that biomasses of cohort 1 fish of the magnitude shown in Table 9 have never been seen in or near Port Moller indicates that all of the biomass estimates for cohort 1 are too large to be realistic. They should not be used for any stock management purpose.

The biomasses of cohort 2 that were estimated using a Pareto-type mortality are also much too large to be realistic, but the biomasses calculated under the assumptions of a constant mortality rate (Z) of 0.5279 d^{-1}, a range of egg survival rates (s_1) of 0.79 to 0.99, and a fractional hatching success (s_2) of 0.71 are reasonable because they are only 1 to 27% times higher than the spawning biomass estimated from aerial surveys in 1989.

This analysis shows that the application of a mortality rate measured from 5 d old cohort 2 larvae to 14 d old cohort 1 larvae leads to unrealistic estimates of spawning biomass. It also shows that the use of a Pareto-type mortality to back-calculate spawning biomass also leads to unrealistically high estimates of biomass. Only when mortality is measured relatively close in time to the spawning date, and mortality is assumed to be constant over the early larval period, is a realistic estimate of spawning biomass produced.

One way of assessing the validity of the calculations shown in Tables 8 and 9 is to calculate the mortality rates that would have been required to produce the number of cohort 2 larvae measured in Port Moller, if the spawning biomass that was observed by aerial surveys was an accurate estimate of true spawning biomass. If survival during incubation and hatching is assumed to range from 0.20 ($s_1 s_2 s_3$ = 0.790.30 0.83) to 0.58

Table 8. Spawning biomass of herring in Port Moller.

Site	x (m)	Area of section (m^2) sub-tidal	Area of section (m^2) inter-tidal	Area of section (m^2) total	Depth of section (m) sub-tidal	Depth of section (m) inter-tidal	Volume of section (m^3) sub-tidal	Volume of section (m^3) inter-tidal	Volume of section (m^3) total	Cohort 1 Estimated density of larvae (m^-3)	Cohort 1 Estimated total number of larvae	Cohort 2 Estimated density of larvae (m^-3)	Cohort 2 Estimated total number of larvae
A	7980	28917525	48498450	77415975	4.4	1.5	127237110	72747675	199984785	0.4863	97251845	13.95010	2769806752
B	14763	21526050"	34234200	55760250	6,0	1.5	129156300	51351300	180507600	0.2881	51999430	7,88844	1423923779
c	19870	28074637	10438838	38513475	5.6	1.5	157217967	15658257	172876224	0.1580	27322433	4.10323	709351024
D	25935	24184387	19256725	43441125	6.4	1.5	154780077	28885088	183665184	0.0616	11305891	1.46982	269954851
E	30962	49017150	9077250	58094400	6.1	1.5	299004615	13615875	312620490	0,0233	7289227	0,51076	159675197
F	36069	95246287	972563	96218850	8.2	1.5	781019553	1458845	782478398	0,0073	5708521	0,14415	112792613
G	48358	216946275	0	216946275	17.2	1.5	3731475930	0	3731475930	0.0002	804553	0,00312	11628615
H	45805	75730200	0	75730200	6,0	1.5	605841600	0	605841600	0,0005	295390	0.00758	4590250
I	57935	35660625	0	35660625	9.6	1.5	342342000	0	342342000	0.0000	2331	0.00007	24794
J	36149	68727750	56473462	125201212	5.6	1.5	384875400	84710193	469585593	0,0072	3359307	0.14110	66259684
K	24100	58548262	69440962	127989225	6.0	1.5	351289572	104161443	455451015	0.0630	28693414	0.17316	78866879
L	18035	26907562	34623225	61530787	3.8	1.5	102248736	51934838	154183573	0.0630	9713565	0,47172	72731107
M	11252	37929937	4733137	42663075	16.4	1.5	622050967	7099706	629150672	0,0630	39636492	1,02805	646795529
N	4389	8234362	778050	9012412	45.4	1.5	247030860	1167075	246197935	0.0630	15636470	1.56614	386713892
0	1676	6548587	324187	6872775	33.9	1.5	196457610	466281	196943891	0,0630	12407465	1.67053	329001640
TOTAL											311426334		7064117006

	Cohort 1	Cohort 2
Parameters: Z	0.528	0.528
t	13.700	5.100
Number new larvae	430797242581	104304867264
s1	0.990	0.990
S2	0,710	0.710
s3	0.830	0.830
Number new eggs	7.38416E+11	1.78786E+11
Fr	200,000	200.000
Spawning biomass (MT)	7384,16	1787.86

Notes:

1. Mean depth of water above mean LLT was calculated from all sampling times.
2. Depths of stations N and O were restricted to 30 m for the purpose of calculating volumes.

Table 9. Estimates of the number of herring eggs and larvae and of spawning biomass.

	constant mortality (Z = 0.5279)				exponential mortality (beta = 2,6218)			
	S1 =0.79		SI =0.99		SI =0.79		s1=0.99	
	s2=0.3	s2=0.71	s2=0.3	s2=0.71	s2=0.3	s2=0.71	s2=0.3	s2=0.71
				Cohort 1				
Nt	' 3.1143x10^8							
NO	4.3080xl0“11				2.9758x1 0^11			
Ne	21.9001x1 0^1 1	9.2536x1 0^1 1	17.4758x1 0^11	7.3842x1 0^11	18.1078 x10^11	7.6512x10^1 1	12.0719x10^11	5.1008x10^II
B	21,900	9,254	17,476	7,384	18,108	7,651	12,072	5,101
				Cohort 2				
Nt	7.0641 x10^9							
NO	**1.0430xl0“11**				5,0602x1 0“11			
Ne	5.3025xIOA11	2.2405x1 0^1 1	4.231 3x1OA11	1 ,7879x1 0^11	30.7909x1 0“11	1 3,0102xIOA11	20.5272x10^1 1	8.6735x1 0^11
B	5,302	2,241	4,231	1,788	30,791	13,010	20,527	8,673

Notes:
Nt = number of larvae at age t;
No . number of larvae at hatch (t=0);
Ne = number of eggs spawned; and
B = spawning biomass (MT).

($s_1 s_2 s_3$ = 0.990.71 0.83), then 3.528x1010 to $1.023x10^{11}$ viable cohort 2 larvae would have been produced from $1.764x10^{11}$ newly-laid eggs. This leads to expected instantaneous larval mortality rates of 0.31 to 0.53 d^{-1} over the first 5 d after hatch. These are high rates of larval mortality compared to those that have been reported in the literature for this species (section 4.4. 1), and so they support the validity of the high rate of larval mortality measured in this study.

If larval mortality is assumed to have been constant at 0.5279 d^{-1} over the first 5 d after hatch, then 59% [=100(1 .0430x10'1 /$1.764x10^{11}$)], of the eggs of cohort 2 are expected to have hatched viable larvae, i.e. $s_1 s_2 s_3$ = 0.59. If a range of egg survivals (s_i) of 79 to 99% is assumed, then 72 to 90% of the surviving eggs must have survived the stress of hatching. A hatching success of this magnitude is within the range reported for light intensities of natural herring spawn, implying that the eggs were laid in Port Moller at densities less than approximately 500,000 eggs m^{-2}. In this regard, it is interesting to note that eelgrass, Zostera, was the only substrate tested by Hourston et al. (1984) to have 100% hatch. Eelgrass is the major herring pawning substrate in Port Moller.

4.4.3 Perturbation analysis

The relative importance of the parameters used to calculate spawning biomass can be obtained by combining equations (10), (11), (12) and (14a) to give

$$(20)\quad B = \frac{2N_t \exp(Z_e t_e + Zt)}{10^6 s_2 s_3 F_r}$$

and then perturbing each of the parameters in equation (20) by-L-5% and $\pm$25%. Table 10 shows that spawning biomass is most sensitive larval mortality, Z, and to the average age of capture of the larvae, t. Spawning biomass was least sensitive to egg mortality, Z_e, and egg incubation time, t_e. Perturbations of the other four parameters result in changes of only -25.0 to +33.3% in the back-calculated spawning biomass. Table 10 also shows that the response of biomass to perturbations in Z and t is approximately twice as great for overestimates of Z and t as it is for underestimates of the two parameters. Asymmetrical responses are also observed for Z_e, t_e, s_2, s_3 and F_r, but with lower magnitudes.

This analysis indicates that correct ageing of the larvae is as important to the back-calculation of spawning biomass as is obtaining a correct estimate of larval mortality rate. It also implies that the accuracy of back-calculated stock biomass would be maximized if the densities of herring larvae were measured as close to the date of hatch as is practical.

Table 10. Response of equation (20) to perturbation of its parameters.

Parameter	-25%	-5%	+5%	+25%
	Perturbation			
Nt	-25.0	-5.0	5.0	25.0
Ze	-3.1	-0.6	0.6	3.3
te	-3.1	-0.6	0.6	3.3
z	-49.0	-12.6	14.3	96.0
t	-49.0	-12.6	14.3	96.0
S2	33.3	5.3	4.8	-20.0
S3	33.3	5.3	4.8	-20.0
Fr	33.3	5.3	4.8	-20.0

Note:
1. Initial parameter values taken from cohort 2.

4.5 Location of spawning habitat

4.5.1 Distribution of intertidal vegetation

Extensive beds of eelgrass were observed at four locations in Moller Bay (Fig. 12A, B):

(1) on the western and eastern shores of Deer Island;

(2) on the tidal flats opposite Harbor Point;

(3) inside Harbor Point; and

(4) off an unnamed bluff that defines the western edge of Right Head.

Narrow strips of eelgrass were observed along the shore between Egg Island and the entrance to Left Head, and scattered bands of Fucus were observed on rocky reefs along the shore of upper Moller Bay opposite Entrance Point and below the bluffs that separate Left and Right Heads.

No vegetation was observed along the Bering Sea coast from Entrance Point to the mouth of Bear River (Fig. 12B).

Scattered bands of eelgrass were observed at three locations in Herendeen bay (Fig. 12C):

(1) along the western shore between Village Spit and Buck Valley;

(2) around Midway Reef between Bluff and Crow Points; and

(3) along the southern shores opposite Grass and Lawrence Valleys.

Scattered Fucus was also seen on rocky substrate below Bluff, Crow and Gull Points. No vegetation was observed in Mud Bay or Nelson Lagoon or along the eastern or western shores of upper Herendeen Bay.

4.5.2 Traditional herring spawning beaches

According to Warren Johnson spawning occurs at six sites in the Port Moller complex each year (Fig. 13A, B, and C). These "consistent" sites are:

(1) the beds of Fucus along the shore of lower Moller Bay opposite Entrance Point;

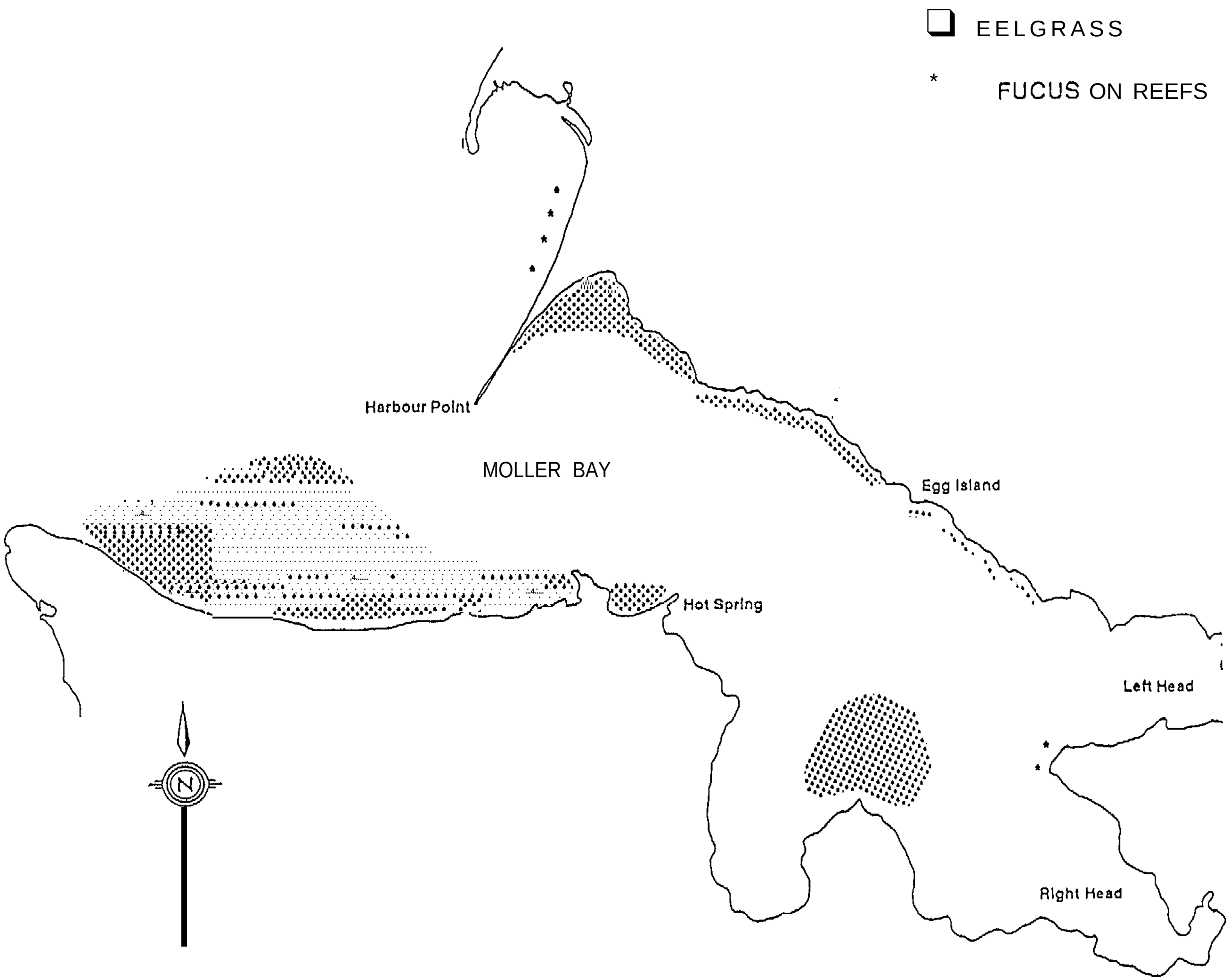


Fig. 12A. Map of intertidal and subtidal vegetation.

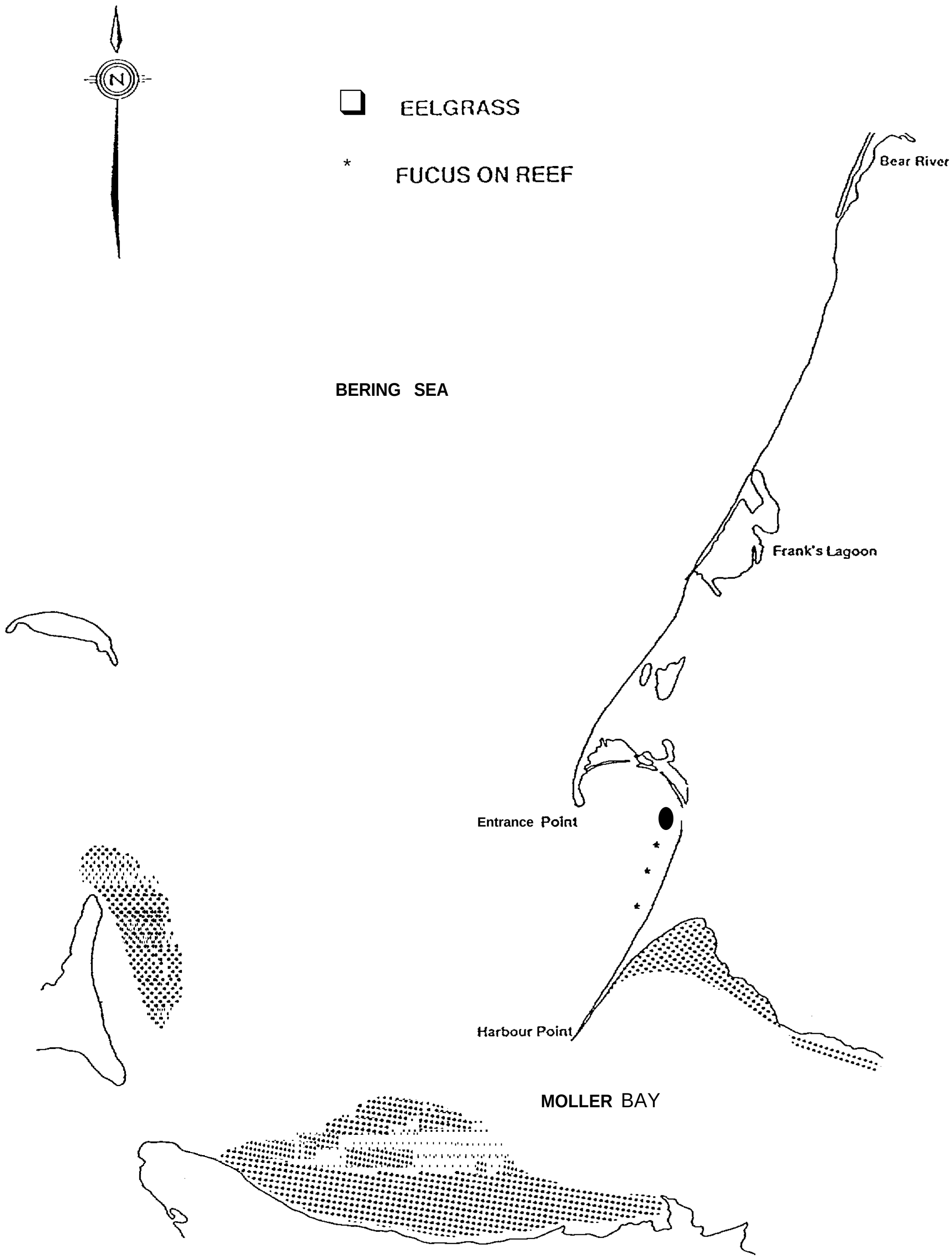


Fig. 12B. Map of intertidal and subtidal vegetation.

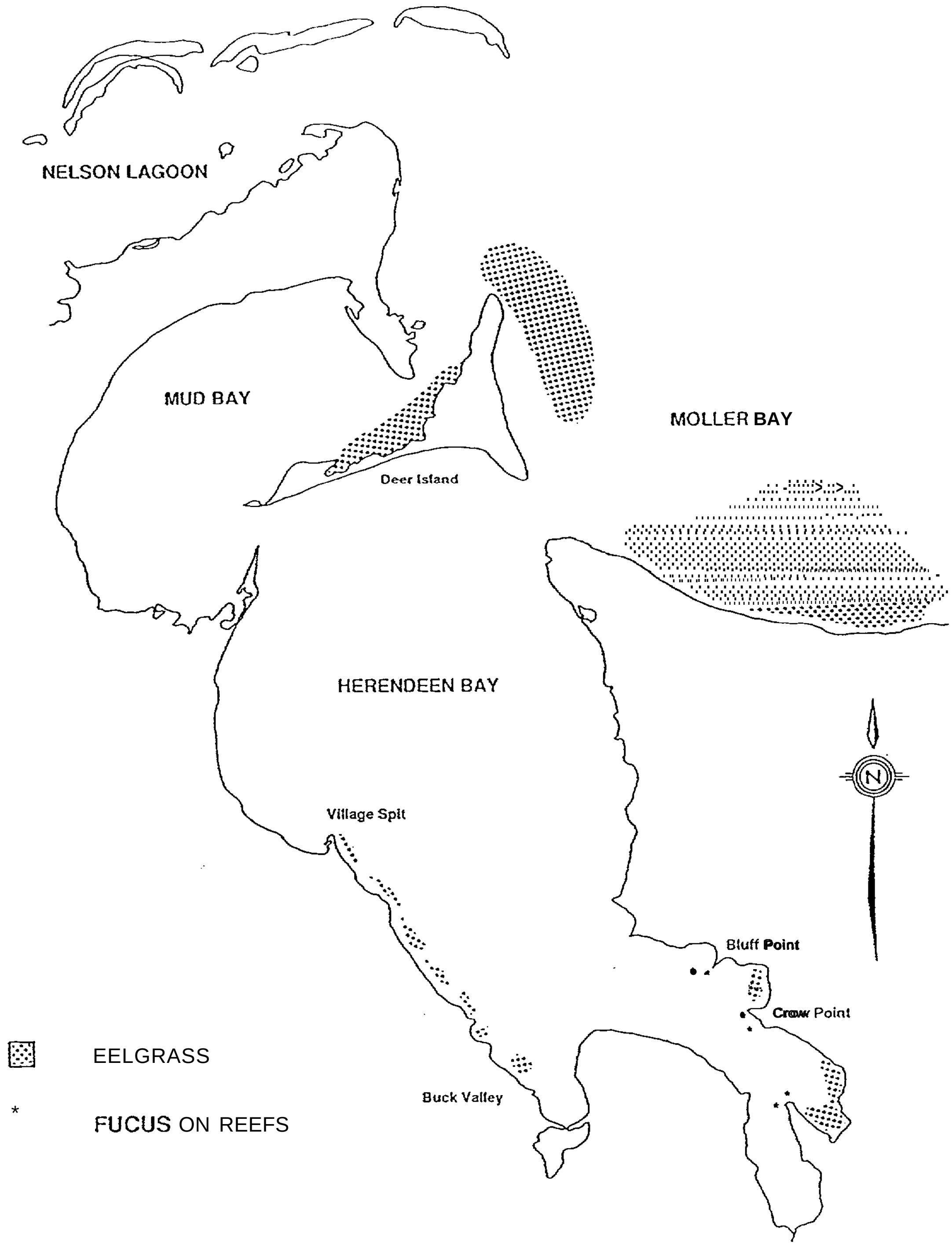


Fig. 12c. Map of intertidal and subtidal vegetation.

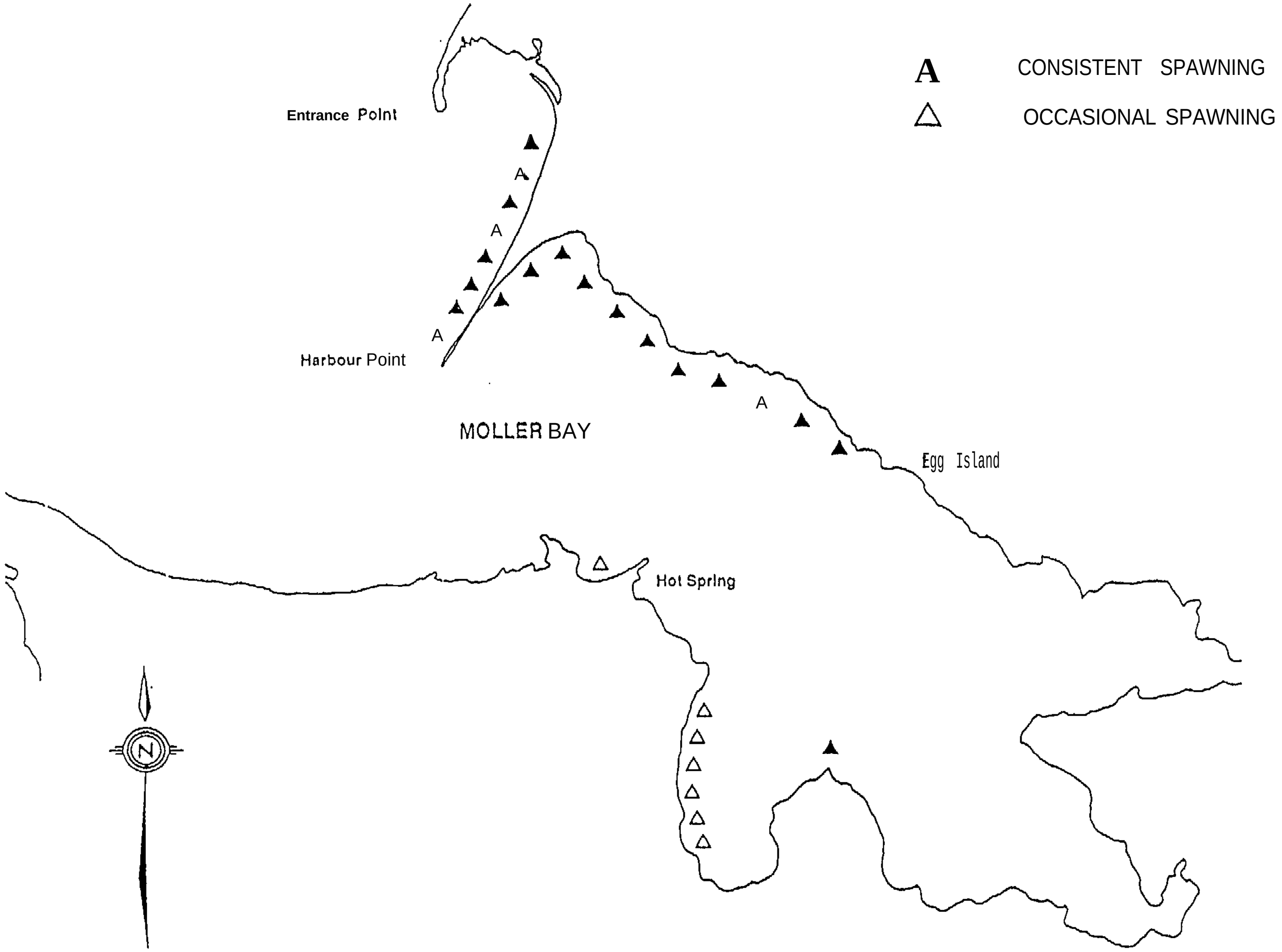


Fig. 13A. Map of herring spawning sites.

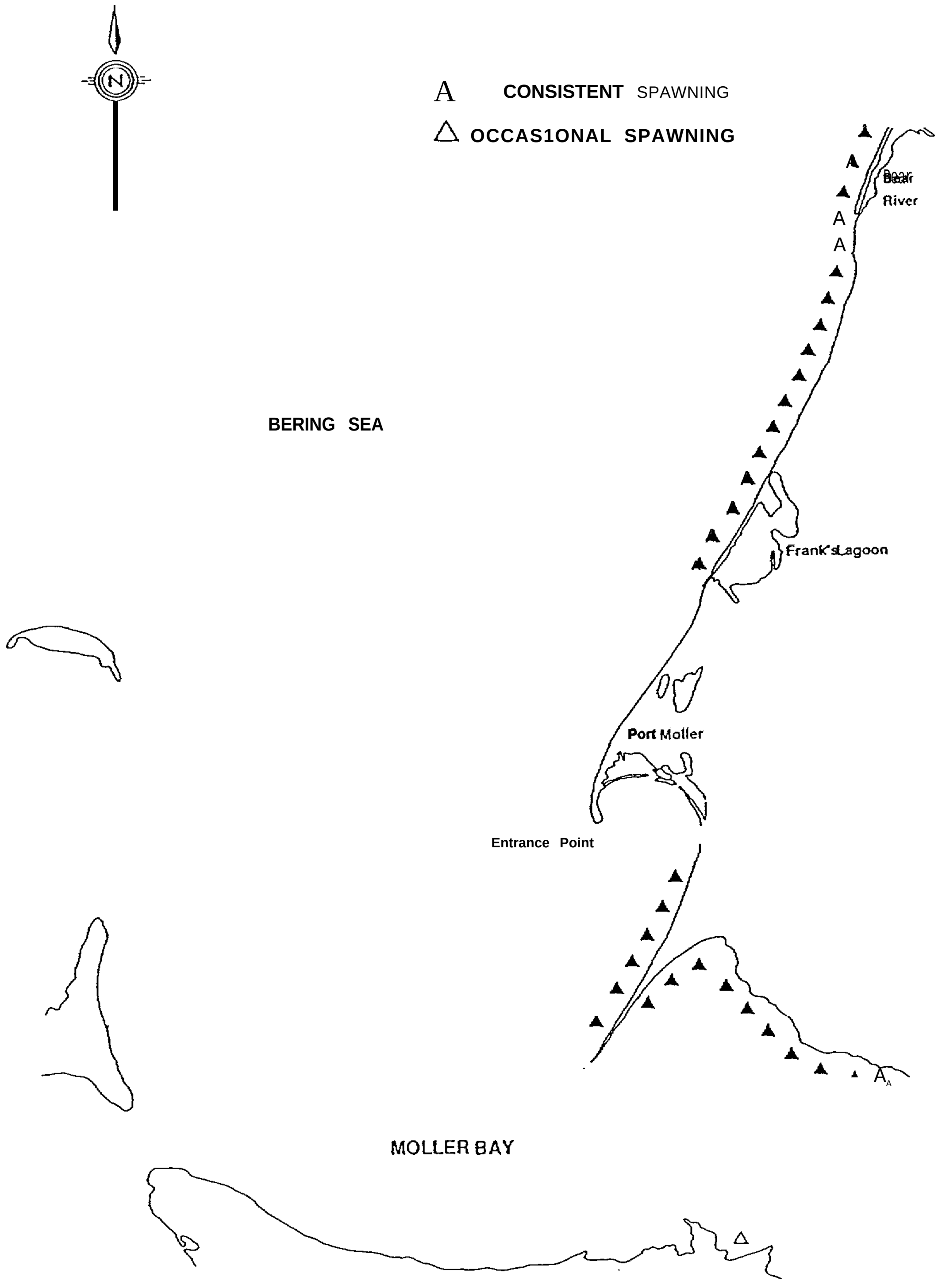


Fig. 13B. Map of herring spawning sites.

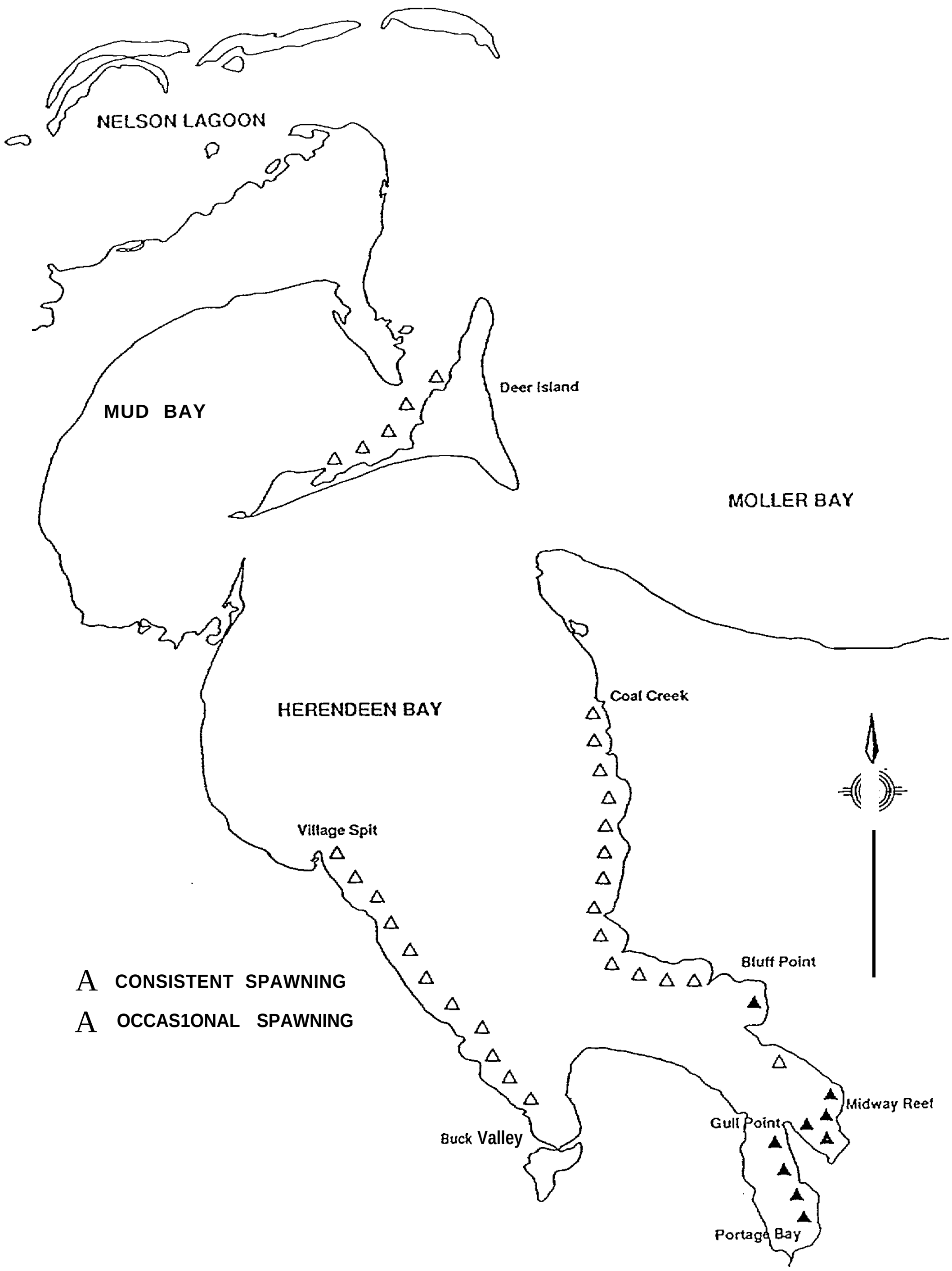


Fig. 13C. Map of herring spawning sites.

(2) the beds of eelgrass inside Harbor Point and extending southeast as far as Egg Island;

(3) the large eelgrass bed off the shore of the unnamed bluff that defines the western edge of Right Head in upper Moller Bay;

(4) the Bering Sea shore from Frank's Lagoon to the mouth of the Bear River;

(5) the eastern shore of Portage Bay and the shoreline of the adjacent Bay to the east; and

(6) the shore just south of Bluff Point.

The site opposite Entrance Point is usually the first to receive spawn. In Moller Bay, the sites of heaviest spawning are inside Harbor Point and opposite the unnamed bluff west of Right Head. In Herendeen Bay, the most concentrated spawning occurs in the southernmost embayments: Portage Bay and the adjacent eastern bay.

Occasional spawning, arbitrarily defined as once every 4 yr, was reported to occur at four sites:

(1) along the shore north and south of Hot Spring;

(2) on the northwestern shore of Deer Island;

(3) on the western shore of Herendeen bay between Village Spit and Buck Valley; and

(4) on the eastern shore of Herendeen Bay between Coal Creek and Bluff Point.

Len Schwarz states that spawning has also been observed on the eastern shore of the peninsula that separates Left and Right Heads of Moller Bay and on the western shore of Portage Bay. It is not known whether these sites are "consistent" or "occasional".

Spawning does not occur often, if it occurs at all, in Left and Right Heads of Moller Bay, even though pre-spawning adults have been seen there. Warren Johnson states that the adults usually aggregate there before moving on to the large eelgrass beds just west of Right Head to spawn. No spawning has been known to occur on the extensive beds of eelgrass along the shore of Moller Bay several kilometers west of Hot Spring, on the Bering Sea shore between Entrance Point and Frank's Lagoon, on the western shore of upper Herendeen Bay, on the southern shore of Deer Island, in Mud Bay, or in Nelson Lagoon.

5.0 Discussion

5.1 Stock structure

The spawn timing reported in this review falls within the range reported by Rounsefell (1930), Wespestad and Barton (1979) and Barton and Wespestad (1980) [see also the review by Hay (1985)]. These authors report that Pacific herring spawn on the north shore of the Alaska Peninsula and in Bristol Bay from early May to mid-June.

The existence of at least 2 separate spawning runs in the same location has been reported in Pacific herring from British Columbia (Hay 1985), and in Atlantic herring from the eastern coast of North America and from the North Sea (Lambert 1984, 1987). Its ubiquity indicates that it is a basic feature of herring stock structure.

Both Lambert (1987) and Hay (1985) report that the runs represent separate age classes, with the oldest fish, usually 5+, spawning first and younger fish spawning in later runs. They report that the number of days between spawning runs ranges from 17 to 25 d, which is very close to the period of time, 18 to 24 d, separating the 2 runs in Port Moller in 1987. This suggests that the spawners observed in June 1987 and June 1989 may have been younger age classses of the same stock as the spawners that were observed in May 1987 and May 1989, respectively, rather than a separate stock.

The age structure of Port Moller herring supports the idea that the 2 groups of spawners in 1987 and 1989 came from the same spawning stock, that older fish spawned first in May, and that younger fish spawned in June. A trend of decreasing modal age of spawners as the spawning season progresses has also been observed in herring from Togiak and Norton Sound (Fried et al. 1982, 1983, Lebida et al. 1986).

The fact that the age structures of both the May and June spawners are similar, apart from the increased proportion of recruit spawners in June, does not support the hypothesis that the 2 spawning runs represent 2 different spawning stocks, unless one assumes that all spawning stocks in the eastern Bering Sea have synchronous year-class strengths, and that different stocks spawn in the same areas. The hypothesis of one stock and age-dependent run timing is the most parsimonious explanation for the origin of multiple spawning runs in Port Moller.

The observation that a June spawning run only occurs about every second year has three explanations. First, it may occur every year but not be reported because: biological data is not collected after the fishery is closed, which usually occurs in May; aerial surveys are unreliable because of the poor ‘seeing’ conditions in Port Moller; and the June spawning run is too small to be observed except during years in which very strong year-classes are passing through the 3 to 5 year old age classes. Two corollaries of this explanation is that the fish which hatched in 1983 produced a strong year-class which appeared as 4 yr olds in 1987, and that the 1988 and 1989 spawning population should have been dominated by 5 and 6 year old fish, respectively. Fig. 5 supports the second prediction, but not the first.

The alternate explanation for the apparent absence of a June spawning run in 1983, 1984, and 1986 is that the run does not occur every year for reasons that are unknown. The first explanation is the most parsimonious one, and it also takes into account the difficulty involved in collecting reliable information from a stock of fish that spawns in one of the most remote locations in Alaska.

The controversy concerning the stock structure of Port Moller herring has obvious relevance for the management of the stock. It is also important for an understanding of the dynamics of the egg and larval stages because the timing of production of larvae in relation to the food production cycle, their spatial distribution within the Port Moller estuary, and the viability of the eggs and larvae are affected by the age, size, and relative abundance of the spawners. For example, recruit spawners produce smaller eggs than 5+ spawners (Kingston 1983), and they spawn several weeks after the older fish at a time (June) when the spring plankton bloom is usually subsiding. Both factors may reduce the survival rate of the larvae that hatch from these eggs.

5.2 Spawning biomass

The biomass of the spawners that produced the cohort 2 larvae was at least 1,764 MT but less than 2,241 MT. Since this group of fish was only the second of three spawning waves, the total size of the Port Moller stock, excluding immature fish, probably close to 3,000 MT.

To my knowledge, this report is the first attempt to compare spawning biomasses of Pacific herring calculated from aerial surveys and larval surveys. The comparison shows that spawning biomass can be estimated from a larval survey, but that the method is so sensitive to the mortality rates of the eggs and young larvae that it can only be used under special circumstances. These include complete spatial coverage of the larvae or at least sufficient coverage to calculate reliable rates of dispersal; temporal coverage sufficient to calculate reliable estimates of larval mortality; accurate ageing of the larvae; and accurate information on the average density of egg deposition.

Larval surveys are impractical for realtime management of a stock because they require too much time to analyse the data.

Despite these restrictions, larval surveys may be useful in assessing spawning biomass in areas such as Port Moller where other techniques of stock assessment are impractical or fail too often to be relied upon. This report is the first review of the information requirements of the larval survey method for Pacific herring. It identifies likely values of important population parameters for Bering Sea herring. Whether or not these parameter values can be applied to other populations can only be known after future studies of this kind have been performed.

5.3 Location of spawning sites

Most of the major herring spawning sites of the Port Moller complex coincide with observed beds of eelgrass and Fucus. The probable sites of spawning identified by the distribution of herring larvae also coincide with these beds. The most likely spawning sites for both cohorts 1 and 2 are the eelgrass beds off Right Head in Moller Bay, and the eelgrass beds south of Bluff Point in Herendeen Bay.

The two exceptions to this pattern are the presence of spawning on the Bering Sea coast between Frank's Lagoon and Bear River despite the absence of vegetation, and the absence of spawning on the shores opposite Harbor Point despite the presence of extensive eelgrass beds.

5.4 Comparison of larval abundance with Auke Bay

The results of this reconnaissance show that the herring that utilize Port Moller are at least one magnitude more abundant than the herring that spawned in Auke Bay in 1988. This is demonstrated by a comparison of larval densities between the two sites:

	Number of herring larvae				Density (m^{-3}) of herring larvae			
Site	mean	SD	n	range	mean	SD	n	range
Port Moller	453	751	25	0-3,165	2.577	4.284	25	0.000-15.146
Auke Bay	13	15	98	0-8	0.168	0.332	98	0.000-1.914

and a comparison of spawning biomasses:

	Spawning biomass (MT)	
Site	cohort 2	cohort 3
Port Moller	1,788-2,241	
Auke Bay	13	6

6.0 Recommendations

1. There is sufficient density of herring larvae in Port Moller to make a study of their population dynamics feasible.

2. Future studies of the early life history stages of Port Moller herring must begin on May 1 and run to at least July 15 because herring in Port Moller spawn in at least three waves beginning in mid-May and ruining to mid-June.

3. Future studies must extend over all parts of Moller and Herendeen Bays because both Bays support separate groups of larvae. The studies should also extend at least as far north as the mouth of the Bear River, since consistent spawning is reported to occur on the coast between Frank's Lagoon and Bear River.

4. Future studies involving plankton sampling must filter more than 187 m^3 of water in each tow in order to be able to reliably detect the presence of herring larvae that are older than 14 d.

5. Future studies should be designed to locate egg beds within Port Moller, identify their relative use by successive waves of spawners, and measure the dynamics of the egg stage because these are important subjects of basic research. They are important not only for assessing the possible impacts of oil development on herring resources in Port Moller, but for measuring the size and structure of the Port Moller herring stock and for testing and refining techniques of stock assessment that may be employed for other herring stocks that spawn in sub-tidal areas of Alaska.

6. The plan for the physical/biological population model of herring larvae in Port Moller should incorporate techniques for measuring daily changes in the magnitude of population parameters. This is especially important for testing the hypothesis that mortality of newly-hatched herring larvae declines exponentially with age, and for measuring the rate of change of mortality as accurately as possible.

7. The causes of the break in coastal current patterns that has been reported to occur at Bear River should be investigated by those responsible for measuring and modelling the hydrodynamics of the Port Moller complex because this may be relevant to the retention of herring larvae within the Port Moller area.

8. The Alaska Department of Fish and Game should be formally requested to compile, analyse, and publish the information they have collected on Port Moller herring. Special attention should be taken to compare age structures and growth curves of separate spawning waves with each other and with those of adjacent stocks in Bristol Bay and the Aleutian Islands in order to test the hypothesis that the Port Moller fish consist of only one stock, and that it is separate from all others in the Bering Sea.

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Appendix A. Dates of Pacific herring fishery in Port Moller, Alaska.

	Herendeen Bay		Moller Bay		Bear River			Percent
Date	catch (MT)	percent roe yield	catch (MT)	percent roe yield	catch (MT)	percent roe yield	Total catch (MT)	of total catch
31-May-82	-	-			42	-	42	9.0
2-Jun-82	60	-					60	12.8
8-Jun-82	-	-	164				164	35.1
10-Jun-82	92	-					92	19.7
12-Jun-82	109	-					109	23.3
	261		164		42		467	100.0
9-May-83	257	-					257	44.4
10-May-83	43	-					43	7.4
14-May-83	2	-					2	0.3
17-May-83	112	-					112	19.3
18-May-83	59	-					59	10.2
19-May-83			55				55	9.5
20-May-83			49				49	8.5
21-May-83			1				1	0.2
29-May-83			1				1	0.2
	473		106		0		579	100.0
24-May-84			149				149	38.0
25-May-84	87	-	68				155	39.5
27-May-84	22	-					22	5.6
28-May-84	1	-					1	0.3
31-May-84	18	-					18	4.6
1-Jun-84	29	-					29	7.4
4-Jun-84	7	-					7	1.8
8-Jun-84			11				11	2.8
	164		228		0		392	100.0
24-May-85	15	-					15	2.3
25-May-85	16	-					16	2.5
26-May-85	27	-					27	4.2
27-May-85	11	-	18				29	4.5
29-May-85	-	-			261		261	40.2
30-May-85	-	-	40				40	6.2
1-Jun-85	-	-	174				174	26.8

Appendix A. Dates of Pacific herring fishery in Port Moller, Alaska.

	Herendeen Bay		Moller Bay		Bear River			Percent
Date	catch (MT)	percent roe yield	catch (MT)	percent roe yield	catch (MT)	percent roe yield	Total catch (MT)	of total catch
4-Jun-85	87						87	13.4
	156		232		261		649	100.0
18-May-86			3				3	0.4
19-May-86			31				31	3.8
20-May-86	102		10				112	13.8
21-May-86					64		64	7.9
22-May-86							0	0.0
23-May-86			1				1	0.1
24-May-86			14		41		55	6.8
25-May-86	4		10		21		35	4.3
26-May-86	34		169		19		222	27.4
27-May-86			1				1	0.1
28-May-86							0	0.0
29-May-86					217		217	26.8
30-May-86					68		68	8.4
	140		239		430		809	100.0
9-May-87	-		18	7.12	-		18	3.9
10-May-87	109	10.44	17	12.62	7	12.04	133	28.5
n-May-87	37	9.31	18	8.99	-		55	11.8
19-May-87	-		48	6.90	-		48	10.3
2-Jun-87	-		103	12.51	-		103	22.1
4-Jun-87	-		83	12.23	-		83	17.8
5-Jun-87	-		26	9.77	-		26	5.6
	146		313		7		466	100.0
28-May-88	4	9.00	-				4	1.5
6-Jun-88	3	7.20	-				3	1.1
9-Jun-88	-		61	7.30	-		61	22.8
10-Jun-88	-		6	5.70	-		6	2.2
12-Jun-88	-		6	8.60	-		6	2.2
16-Jun-88	-		124	8.50	-		124	46.4
17-Jun-88	-		63	9.00	-		63	23.6
	7		260				267	100.0

Appendix A. Dates of Pacific herring fishery in Port Moller, Alaska.

Date	Herendeen Bay catch (MT)	Herendeen Bay percent roe yield	Moller Bay catch (MT)	Moller Bay percent roe yield	Bear River catch (MT)	Bear River percent roe yield	Total catch (MT)	Percent of total catch
29-May-89	-	-	284	9.80	-	-	284	63.1
16-Jun-89	28	9.40	-	-	-	-	28	6.2
17-Jun-89	33	8.70	80	8.60	-	-	113	25.1
23-Jun-89	-	-	25	10.00	-	-	25	5.6
	62		389		-		450	100.0

Notes:

1. Catches are processed herring boxed weights.
2. Dashes indicate data not taken or recorded.

Appendix B. Biomass (MT) of spawning herring in Port Moller estimated by aerial surveys by the Alaska Department of Fish and Game.

Date	Deer Island	Herendeen Bay	Moller Bay	Bear River	Total	Survey Rating
6-May-83		o	82		82	
4-May-84		0	0	0	0	
10-May-84		0	0		0	
16-May-84		0	0	0	0	
19-May-84		0	0		0	
22-May-84		454	-		454	
23-May-84		0	36	4	40	
25-May-84		120	402	0	522	
26-May-84		136	80		216	
27-May-84		187	60	0	247	
30-May-84		82	71	0	153	
6-Jun-84		61	0	0	61	
7-Jun-84		123	0		123	
14-Jun-84		0	-		0	
18/30-May-86		no major biomass sightings				
6-May-87		0			0	
7-May-87		0			0	
10-May-87		0	0	-	0	
n-May-87		0	0	0	0	
15-May-87		0	15	-	15	
16-May-87		0	0	-	0	
17-May-87				0	0	
19-May-87			0	-	0	
24-May-87		0			0	
30-May-87				0	0	
3 l-May-87				0	0	
1-Jun-87		0	0	-	0	
2-Jun-87	. -	0	5000	2	5002	
3-Jun-87	-	0	110	0	110	
17-May-88	0	18	0	0	18	1.5
19-May-88	0	12	0	0	12	2.5
23-May-88	0	354	204	0	558	2.0

Appendix B. Biomass (MT) of spawning herring in Port Moller estimated by aerial surveys by the Alaska Department of Fish and Game.

Date	Deer Island	Herendeen Bay	Moller Bay	Bear River	Total	Survey Rating
26-May-88	91	0	-	-	91	2.0
27-May-88	6	44	0	0	50	2.5
28-May-88	0	0	0	-	0	2.3
29-May-88	7	105	0	0	112	2.3
30-May-88	21	359	0	0	380	2.8
31-May-88			0	0	0	2.5
1-Jun-88	0	634	0	0	634	2.8
3-Jun-88	0	709	197	0	906	1.5
6-Jun-88	0	0	0	0	0	2.0
9-Jun-88		0	0	-	0	3.0
10-Jun-88			0	7	7	2.0
11-Jun-88	0	-	0	-	0	2.0
15-Jun-88	0	-			0	3.0
19-May-89	0	0	-	-	0	4.0
22-May-89	0	0	0	0	0	3.5
23-May-89	0	0	0	-	0	2.7
25-May-89	0	0	0	0	0	2.5
29-May-89			0	1182	1182	2.0
29-May-89			0	726	726	2.0
30-May-89	14	1002	157	0	1173	2.0
30-May-89	0	14	748	0	762	2.0
31-May-89	0	0	7	0	7	2.8
2-Jun-89	0	0	7	0	7	2.3
13-Jun-89	0	42	259	-	301	2.3
15-Jun-89			154	-	154	2.0
16-Jun-89			332	-	332	2.0

Notes:
1. Dashes indicate no data.
2. Survey rating:
   1 = excellent (calm, no glare)
   2 = good (light ripple, uneven lighting, easy to spot schools)
   3 = fair (light chop, some glare or shadows, relatively easy to spot schools)
   4 = poor (rough seas, strong glare, difficult to spot schools)
   5 = unsatisfactory

Appendix C. Age structure of Port Moller herring.

Date	Age	Moller Bay inner	Moller Bay outer	Moller Bay total	Herendeen Bay	Bear River	Total	Percent of total
May/June-76	3				28	-	28	14.7
	4				120	-	120	63.2
	5				30	-	30	15.8
	6				9	-	9	4.7
	7				2	-	2	1.1
	8				0	-	0	0.0
	9				1	-	1	0.5
	10				0	-	0	0.0
	11				0	-	0	0.0
Total					190	-	190	100.0
May-81	3			2	14	-	16	5.7
	4			134	72	-	206	72.8
	5			22	14	-	36	12.7
	6			5	6	-	11	3.9
	7			4	5	-	9	3.2
	8			2	2	-	4	1.4
	9			1	0	-	1	0.4
	10			0	0	-	0	0.0
	11			0	0	-	0	0.0
Total				170	113	-	283	100.0
May-82	3	-	-	15	-	-	15	2.8
	4	-	-	115	-	-	115	21.5
	5	-	-	275	-	-	275	51.4
	6	-	-	41	-	-	41	7.7
	7	-	-	9	-	-	9	1.7
	8	-	-	41	-	-	41	7.7
	9	-	-	29	-	-	29	5.4
	10	-	-	10	-	-	10	1.9
	11	-	-	0	-	-	0	0.0
Total				535	-	-	535	100.0

Appendix C. Age structure of Port Moller herring.

Date	Age	Moller Bay inner	Moller Bay outer	Moller Bay total	Herendeen Bay	Bear River	Total	Percent of total
9/29-May-83	3	-	-	0	6	-	6	0.5
	4	-	-	16	26	-	42	3.6
	5	-	-	109	212	-	321	27.3
	6	-	-	167	524	-	691	58.7
	7	-	-	12	52	-	64	5.4
	8	-	.-	4	12	-	16	1.4
	9	-	-	3	19	-	22	1.9
	10	-	-	3	6	-	9	0.8
	11	-	-	0	6	-	6	0.5
Total				314	863	0	1177	100.0
May 24/June 1-85	3	6	23	29	0	0	29	3.1
	4	59	297	356	4	7	367	39.8
	5	42	120	162	4	29	195	21.1
	6	75	77	152	6	57	215	23.3
	7	168	26	194	7	57	258	28.0
	8	137	15	152	5	65	222	24.1
	9	12	0	12	0	3	15	1.6
	10	1	2	3	0	2	5	0.5
	11	10	1	11	1	2	14	1.5
		110	562	672	27	223	922	100.0
18/29-May-86	3	4	0	4	5	1	10	1.1
	4	20	0	20	39	9	68	7.2
	5	58	5	63	100	76	239	25.2
	6	33	7	40	53	39	132	13.9
	7	50	15	65	40	61	166	17.5
	8	55	21	76	28	63	167	17.6
	9	57	15	72	35	51	158	16.6
	10	2	0	2	1	3	6	0.6
	11	3	0	3	0	0	3	0.3
Total		282	63	345	301	303	949	100.0

Appendix C. Age structure of Port Moller herring.

Date	Age	Moller Bay inner	Moller Bay outer	Moller Bay total	Herendeen Bay	Bear River	Total	Percent of total
10-May-87	3	1	0	1	4	0	5	1.4
	4	2	0	2	7	1	10	2.7
	5	14	2	16	40	0	56	15.3
	6	37	3	40	44	5	89	24.4
	7	15	3	18	31	3	52	14.2
	8	15	7	22	24	12	58	15.9
	9	27	17	44	18	3	65	17.8
	10	11	1	12	11	3	26	7.1
	11	0	0	0	4	0	4	1.1
Total		122	33	155	183	27	365	100.0
19-May-87	3	5	-	5	-		5	2.8
	4	21	-	21	-		21	11.8
	5	35	-	35	-		35	19.7
	6	34	-	34	-		34	19.1
	7	27	-	27	-		27	15.2
	8	11	-	11	-		11	6.2
	9	20	-	20	-		20	11.2
	10	25	-	25	-		25	14.0
	11	0	-	0	-		0	0.0
Total		178	-	178	-		178	100.0
4-Jun-87	3	1	1	2	-		2	1.1
	4	20	48	68	-		68	36.8
	5	2	9	11	-		11	5.9
	6	15	14	29	-		29	15.7
	7	5	5	10	-		10	5.4
	8	18	11	29	-		29	15.7
	9	20	8	28	-		28	15.1
	10	5	3	8	-		8	4.3
	11	0	0	0	-		0	0.0
Total		86	99	185	-		185	100.0

Appendix C. Age structure of Port Moller herring.

Date	Age	Moller Bay inner	Moller Bay outer	Moller Bay total	Herendeen Bay	Bear River	Total	Percent of total
Total		86	99	185	-	-	185	100.0
May 28/June 6-88	3	-	-	-	6	-	6	2.8
	4	-	-	-	48	-	48	22.6
	5	-	-	-	63	-	63	29.7
	6	-	-	-	47	-	47	22.2
	7	-	-	-	19	-	19	9.0
	8-	-		-	8	-	8	3.8
	9	-	-	-	7	-	7	3.3
	10	-	-	-	7	-	7	3.3
	11	-	-	-	7	-	7	3.3
					212	-	212	100.0
June 9/16-88	3	3	-	3	-		3	0.9
	4	99	-	99	-		99	29.8
	5	96	-	96	-		96	28.9
	6	39	-	39	-		39	11.7
	7	20	-	20	-		20	6.0
	8	16	-	16	-		16	4.8
	9	16	-	16	-		16	4.8
	10	25	-	25	-		25	7.5
	11	18	-	18	-		18	5.4
		332	-	332	-		332	100.0

Notes:
1. Dashes indicate no data.
2. Herendeen Bay includes catches taken near Deer Island.
3. Bear River includes all catches taken north of Frank's Lagoon.
4. Data for 1976 from Warner and Shafford (1979).
5. Data for 1981-1989 from annual reports by the Alaska Department of Fish and Game, Kodiak.

Appendix D. Temperature, salinity and conductivity profiles of Port Moller.

Date	Site code	Time	Depth (m)	Temp (degC)	conduct. (mmho/cm)	salinity (ppt)
10-Jun-89	D	1115	0	8.22		
10-Jun-89	D	1115	2	8.20		
10-Jun-89	D	1115	0	8.22		
10-Jun-89	D	1115	2	8.20		
10-Jun-89	D	1115	4	8.28		
10-Jun-89	D	1115	6	8.21		
10-Jun-89	D	1115	8	8.30		
10-Jun-89	D	1115	10	8.25		
10-Jun-89	D	1115	12	8.22		
10-Jun-89	D	1115	14	8.09		
10-Jun-89	D	1115	16	8.21		
10-Jun-89	D	1115	18	8.00		
10-Jun-89	D	1115	20	8.11		
			MEAN	8.19		
			SD	0.09		
			N	11		
11-Jun-89	D	0945	0	8.24	27.66	25.84
11-Jun-89	D	0945	2	8.15	27.65	25.83
11-Jun-89	D	0945	4	8.23	27.66	25.77
11-Jun-89	D	0945	6	8.19	27.66	25.74
11-Jun-89	D	0945	8	8.32	27.70	25.72
11-Jun-89	D	0945	10	8.23	27.77	25.79
11-Jun-89	D	0945	12	8.19	27.72	25.98
11-Jun-89	D	0945	14	8.15	27.73	25.88
11-Jun-89	D	0945	16	8.47	27.75	25.60
11-Jun-89	D	0945	18	9.05	27.82	26.59
11-Jun-89	D	0945	20	8.10	27.78	25.72
11-Jun-89	D	0945	22	8.90	27.80	25.54
11-Jun-89	D	0945	24	8.60	27.75	25.80
11-Jun-89	D	0945	26	8.20	27.78	26.00
11-Jun-89	D .	0945	28	8.32	27.79	25.84
11-Jun-89	D	0945	30	8.20	27.78	26.10
			MEAN	8.346		25.859
			SD	0.28		0.24
			N	16		16

Appendix D. Temperature, salinity and conductivity profiles of Port Moller.

Date	Site code	Time	Depth (m)	Temp (degC)	conduct. (mmho/cm)	salinity (ppt)
11-Jun-89	A	1200	4	9.15	25.38	22.90
11-Jun-89	A	1200	6	9.18	25.43	22.90
11-Jun-89	A	1200	8	9.15	25.44	22.98
11-Jun-89	A	1200	10	9.04	25.42	22.74
11-Jun-89	A	1200	12	9.14	25.44	22.98
			MEAN	9.153		22.513
			SD	0.06		0.70
			N	7		7
11-Jun-89	F	1555	0	8.49	27.93	26.00
11-Jun-89	F	1555	2	8.16	27.85	26.06
11-Jun-89	F	1555	4	8.00	27.88	26.31
11-Jun-89	F	1555	6	7.94	27.90	26.41
11-Jun-89	F	1555	8	7.82	27.92	26.50
11-Jun-89	F	1555	10	7.70	27.90	26.50
11-Jun-89	F	1555	12	7.87	27.92	26.30
11-Jun-89	F	1555	14	7.70	27.97	26.51
11-Jun-89	F	1555	16	7.64	27.97	26.54
11-Jun-89	F	1555	18	7.74	27.97	26.60
			MEAN	7.906		26.373
			SD	0.26		0.20
			N	10		10
12-Jun-89	H	925	0	7.60	27.92	26.81
12-Jun-89	H	925	2	7.25	28.02	27.11
12-Jun-89	H	925	4	7.14	28.00	27.11
12-Jun-89	H	925	6	7.05	27.96	27.20
12-Jun-89	H	925	8	7.16	27.94	27.20
12-Jun-89	H	925	10	7.14	27.96	27.19
12-Jun-89	H	925	12	7.06	27.88	27.18
			MEAN	7.2		27.114
			SD	0.19		0.14
			N	7		7
12-Jun-89	I	1000	0	7.27	27.37	26.35
12-Jun-89	I	1000	2	6.96	27.84	26.87
12-Jun-89	I	1000	4	6.68	27.77	27.06

Appendix D. Temperature, salinity and conductivity profiles of Port Moller.

Date	Site code	Time	Depth (m)	Temp (degC)	conduct. (mmho/cm)	salinity (ppt)
12-Jun-89	I	1000	6	6.60	27.77	27.24
12-Jun-89	I	1000	8	6.52	27.73	27.24
12-Jun-89	I	1000	10	6.33	27.64	27.25
12-Jun-89	I	1000	12	5.94	27.34	27.41
			MEAN	6.614		27.060
			SD	0.43		0.36
			N	7		7
12-Jun-89	G	1125	0	7.77	27.83	26.49
12-Jun-89	G	1125	2	7.44	27.73	26.48
12-Jun-89	G	1125	4	7.37	27.70	26.64
12-Jun-89	G	1125	6	7.25	27.68	26.70
12-Jun-89	G	1125	8	7.22	27.67	26.77
12-Jun-89	G	1125	10	7.19	27.67	26.77
12-Jun-89	G	1125	12	7.17	27.69	26.84
			MEAN	7.344		26.670
			SD	0.21		0.14
			N	7		7
12-Jun-89	K	1300	0	8.98	28.40	26.20
12-Jun-89	K	1300	2	8.70	28.34	26.20
12-Jun-89	K	1300	4	8.77	28.60	26.60
12-Jun-89	K	1300	6	8.86	28.51	28.35
12-Jun-89	K	1300	8	8.74	28.65	26.49
12-Jun-89	K	1300	10	8.72	28.61	26.65
12-Jun-89	K	1300	12	8.59	28.58	26.62
12-Jun-89	K	1300	14	8.78	28.60	26.72
12-Jun-89	K	1300	16	8.47	28.56	26.72
12-Jun-89	K	1300	18	8.53	28.52	26.46
12-Jun-89	K	1300	20	8.46	28.40	26.50
12-Jun-89	K	1300	22	8.54	28.53	26.64
12-Jun-89	K	1300	24	8.42	28.38	26.51
12-Jun-89	K	1300	26	8.45	28.35	26.50
12-Jun-89	K	1300	28	8.42	28.35	26.61
12-Jun-89	K	1300	30	8.34	28.35	26.58
			MEAN	8.611		26.647
			SD	0.19		0.48

Appendix D. Temperature, salinity and conductivity profiles of Port Moller.

Date	Site code	Time	Depth (m)	Temp (degC)	conduct. (mmho/cm)	salinity (ppt)
			N	16		16
12-Jun-89	O	1500	0	8.64	25.42	23.37
12-Jun-89	O	1500	2	8.26	25.82	24.15
12-Jun-89	O	1500	4	7.97	26.12	24.54
12-Jun-89	O	1500	6	6.85-	25.66	24.37
12-Jun-89	O	1500	8	6.75	25.75	24.54
12-Jun-89	O	1500	10	6.72	25.78	24.64
12-Jun-89	O	1500	12	6.68	25.73	24.87
12-Jun-89	O	1500	14	6.72	25.73	24.82
12-Jun-89	O	1500	16	6.55	25.68	24.86
12-Jun-89	O	1500	18	6.38	25.64	25.00
12-Jun-89	O	1500	20	6.32	25.55	24.89
12-Jun-89	O	1500	22	6.50	25.54	25.02
12-Jun-89	O	1500	24	6.16	25.39	25.00
12-Jun-89	O	1500	26	6.24	25.32	24.94
12-Jun-89	O	1500	28	5.65	25.18	25.00
12-Jun-89	O	1500	30	5.30	25.04	25.20
			MEAN	6.731		24.701
			SD	0.88		0.45
			N	16		16
12-Jun-89	M	1610	0	9.30	27.09	24.30
12-Jun-89	M	1610	2	9.17	27.11	24.60
12-Jun-89	M	1610	4	8.30	27.20	25.41
12-Jun-89	M	1610	6	7.80	27.07	25.51
12-Jun-89	M	1610	8	7.51	27.01	25.59
12-Jun-89	M	1610	10	7.54	27.01	25.59
12-Jun-89	M	1610	12	7.46	26.98	25.55
12-Jun-89	M	1610	14	7.24	26.82	25.67
12-Jun-89	M	1610	16	7.10	26.77	25.71
12-Jun-89	M .	1610	18	6.98	26.71	25.55
12-Jun-89	M	1610	20	6.65	26.53	25.55
12-Jun-89	M	1610	22	6.48	26.36	25.75
12-Jun-89	M	1610	24	6.22	26.33	26.03
12-Jun-89	M	1610	26	6.13	26.18	25.86
12-Jun-89	M	1610	28	6.42	24.25	23.20

Appendix D. Temperature, salinity and conductivity profiles of Port Moller.

Date	Site code	Time	Depth (m)	Temp (degC)	conduct. (mmho/cm)	salinity (ppt)
			MEAN	7.353		25.325
			SD	0.98		0.74
			N	15		15
13-Jun-89	D	0911	0	8.88	28.37	26.10
13-Jun-89	D	0911	2	8.87	28.39	26.10
13-Jun-89	D	0911	4	8.86	28.43	26.12
13-Jun-89	D	0911	6	8.86	28.42	26.08
13-Jun-89	D	0911	8	8.82	28.45	26.28
13-Jun-89	D	0911	10	8.68	28.48	26.25
13-Jun-89	D	0911	12	8.70	28.48	26.35
13-Jun-89	D	0911	14	8.70	28.48	26.40
13-Jun-89	D	0911	16	8.76	28.48	26.32
13-Jun-89	D	0911	18	8.74	28.46	26.35
13-Jun-89	D	0911	20	8.78	28.46	26.28
13-Jun-89	D	0911	22	8.81	28.48	26.30
13-Jun-89	D	0911	24	8.67	28.48	26.28
13-Jun-89	D	0911	26	8.78	28.46	26.37
13-Jun-89	D	0911	28	8.81	28.46	26.24
13-Jun-89	D	0911	30	8.73	28.46	26.26
			MEAN	8.778		26.255
			SD	0.07		0.10
			N	16		16
13-Jun-89	C	1435	0	10.78	10.58	8.60
13-Jun-89	C	1435	2	10.43	11.32	9.34
13-Jun-89	C	1435	4	10.52	21.39	18.30
13-Jun-89	C	1435	6	10.28	24.36	21.33
13-Jun-89	C	1435	8	10.00	26.33	23.34
13-Jun-89	C	1435	0	9.89	25.99	22.99
13-Jun-89	C	1435	2	9.85	24.02	21.30
13-Jun-89	C	1435	4	10.00	18.150	15.59
			MEAN	10.22		17.599
			SD	0.34		5.90
			N	8		8
13-Jun-89	A	1520	0	11.30	26.58	22.78

Appendix D. Temperature, salinity and conductivity profiles of Port Moller.

Date	Site code	Time	Depth (m)	Temp (degC)	conduct. (mmho/cm)	salinity (ppt)
13-Jun-89	A	1520	2	11.29	26.66	22.87
13-Jun-89	A	1520	4	11.25	26.66	22.99
13-Jun-89	A	1520	6	10.84	26.50	23.16
13-Jun-89	A	1520	8	10.75	26.60	23.20
13-Jun-89	A	1520	10	10.79	26.67	23.31
13-Jun-89	A	1520	12	10.96	27.00	23.39
13-Jun-89	A	1520	14	10.83	27.13	23.66
13-Jun-89	A	1520	16	11.03	27.13	23.61
			MEAN	11		23.219
			SD	0.22		0.31
			N	9		9
13-Jun-89	D	1640	0	9.75	27.67	24.83
13-Jun-89	D	1640	2	9.60	27.62	24.77
13-Jun-89	D	1640	4	9.49	27.64	24.90
13-Jun-89	D	1640	6	9.42	27.65	25.01
13-Jun-89	D	1640	8	9.34	27.67	24.86
13-Jun-89	D	1640	10	9.50	27.62	25.02
			MEAN	9.517		24.898
			SD	0.14		0.10
			N	6		6
13-Jun-89	E	1725	0	9.08	28.70	26.31
13-Jun-89	E	1725	2	9.08	28.71	26.30
13-Jun-89	E	1725	4	8.98	28.71	26.22
13-Jun-89	E	1725	6	9.11	28.68	26.37
13-Jun-89	E	1725	8	8.97	28.68	26.21
13-Jun-89	E	1725	10	9.06	28.68	26.30
13-Jun-89	E	1725	12	9.10	28.66	26.33
13-Jun-89	E	1725	14	9.10	28.66	26.17
13-Jun-89	E	1725	16	9.09	28.67	26.44
			MEAN	9.063		26.294
			SD	0.06		0.08
			N	9		9
14-Jun-89	F	0810	0	8.24	28.32	26.59
14-Jun-89	F	0810	2	8.14	28.30	26.62

Appendix D. Temperature, salinity and conductivity profiles of Port Moller.

Date	Site code	Time	Depth (m)	Temp (degC)	conduct. (mmho/cm)	salinity (ppt)
14-Jun-89	F	0810	4	8.14	28.27	26.69
14-Jun-89	F	0810	6	8.06	28.27	26.70
14-Jun-89	F	0810	8	8.04	28.24	26.66
14-Jun-89	F	0810	10	8.10	28.25	26.74
14-Jun-89	F	0810	12	8.09	28.25	26.72
14-Jun-89	F	0810	14	8.05	28.24	26.71
14-Jun-89	F	0810	16	8.04	28.24	26.71
14-Jun-89	F	0810	18	8.01	28.24	26.67
			MEAN	8.091		26.681
			SD	0.04		0.05
			N	10		10
14-Jun-89	J	1400	0	9.12	27.98	25.55
14-Jun-89	J	1400	2	9.15	28.03	25.55
14-Jun-89	J	1400	4	9.12	27.93	25.53
14-Jun-89	J	1400	6	9.16	27.93	25.54
14-Jun-89	J	1400	8	9.05	27.93	25.50
			MEAN	9.12		25.534
			SD	0.04		0.02
			N	5		5
14-Jun-89	N	0945	0	8.64	20.70	17.60
14-Jun-89	N	0945	2	9.55	19.71	17.36
14-Jun-89	N	0945	4	9.56	19.89	17.45
14-Jun-89	N	0945	6	9.30	19.80	17.60
14-Jun-89	N	0945	8	8.63	19.90	18.00
14-Jun-89	N	0945	10	7.36	19.28	18.03
14-Jun-89	N	0945	12	7.35	19.37	18.18
14-Jun-89	N	0945	14	7.08	19.17	18.00
14-Jun-89	N	0945	16	6.80	19.03	18.01
14-Jun-89	N	0945	18	6.52	18.86	18.01
14-Jun-89	N	0945	20	6.26	18.69	17.95
14-Jun-89	N	0945	22	6.06	18.60	17.99
14-Jun-89	N	0945	24	5.87	18.52	18.04
14-Jun-89	N	0945	26	5.76	18.48	18.09
14-Jun-89	N	0945	28	5.56	18.35	17.92
14-Jun-89	N	0945	30	5.28	18.12	17.86

Appendix D. Temperature, salinity and conductivity profiles of Port Moller.

Date	Site code	Time	Depth (m)	Temp (degC)	conduct. (mmho/cm)	salinity (ppt)
			MEAN	7.224		17.881
			SD	1.48		0.24
			N	16		16
14-Jun-89	M	1100	0	9.77	24.93	22.10
14-Jun-89	M	1100	2	10.24	26.52	23.43
14-Jun-89	M	1100	4	9.73	26.42	23.74
14-Jun-89	M	1100	6	8.87	26.29	24.16
14-Jun-89	M	1100	8	8.57	26.13	24.37
14-Jun-89	M	1100	10	8.13	26.02	24.53
14-Jun-89	M	1100	12	8.02	26.02	24.40
14-Jun-89	M	1100	14	7.59	25.76	24.54
14-Jun-89	M	1100	16	7.50	25.67	24.54
14-Jun-89	M	1100	18	7.19	25.44	24.42
14-Jun-89	M	1100	20	7.16	25.39	24.57
14-Jun-89	M	1100	22	6.94	25.33	24.64
14-Jun-89	M	1100	24	6.65	25.70	25.22
14-Jun-89	M	1100	26	6.16	25.43	25.61
			MEAN	8.037		24.305
			SD	1.25		0.83
			N	14		14
14-Jun-89	L	1155	0	10.28	25.95	22.80
14-Jun-89	L	1155	2	9.00	27.01	24.66
14-Jun-89	L	1155	4	8.95	27.05	24.77
14-Jun-89	L	1155	6	8.89	27.09	24.80
14-Jun-89	L	1155	8	8.86	27.17	24.92
14-Jun-89	L	1155	10	8.85	27.29	25.01
14-Jun-89	L	1155	12	8.87	27.46	25.08
			MEAN	9.1		24.577
			SD	0.52		0.80
			N	7		7
14-Jun-89	K	1325	0	9.20	28.19	25.72
14-Jun-89	K	1325	2	9.19	28.22	25.82
14-Jun-89	K	1325	4	9.21	28.20	25.81
14-Jun-89	K	1325	6	9.14	28.14	25.66

Appendix D. Temperature, salinity and conductivity profiles of Port Moller.

Date	Site code	Time	Depth (m)	Temp (degC)	conduct. (mmho/cm)	salinity (ppt)
14-Jun-89	K	1325	8	9.21	28.18	25.71
14-Jun-89	K	1325	10	9.20	28.12	25.70
14-Jun-89	K	1325	12	9.24	28.14	25.74
14-Jun-89	K	1325	14	9.08	28.21	25.77
14-Jun-89	K	1325	16	9.20	28.21	25.64
14-Jun-89	K	1325	18	9.04	28.21	25.77
14-Jun-89	K	1325	20	9.23	28.21	25.73
14-Jun-89	K	1325	22	9.22	28.21	25.85
14-Jun-89	K	1325	24	9.04	28.24	25.84
14-Jun-89	K	1325	26	9.14	28.24	25.89
14-Jun-89	K	1325	28	9.03	28.19	25.81
14-Jun-89	K	1325	30	9.01	28.22	25.86
			MEAN	9.149		25.770
			SD	0.08		0.07
			N	16		16
14-Jun-89	A	1635	0	11.65	4.79	3.76
14-Jun-89	A	1635	2	11.28	4.95	3.89
14-Jun-89	A	1635	4	11.30	5.43	4.32
14-Jun-89	A	1635	6	11.36	5.54	4.40
14-Jun-89	A	1635	8	11.24	5.65	4.53
14-Jun-89	A	1635	10	11.23	5.66	4.52
14-Jun-89	A	1635	12	11.26	5.69	4.52
			MEAN	11.33		4.277
			SD	0.15		0.32
			N	7		7
14-Jun-89	B	1717	0	10.50	26.96	23.67
14-Jun-89	B	1717	2	10.45	27.00	23.64
14-Jun-89	B	1717	4	10.34	27.00	23.71
14-Jun-89	B	1717	6	10.32	27.00	23.74
14-Jun-89	B	1717	8	10.30	27.01	23.79
14-Jun-89	B	1717	10	10.31	27.01	23.80
14-Jun-89	B	1717	12	10.28	27.01	23.80
14-Jun-89	B	1717	14	10.21	27.01	23.70
14-Jun-89	B	1717	16	10.18	27.01	23.81
14-Jun-89	B	1717	18	10.36	26.99	23.88

Appendix D. Temperature, salinity and conductivity profiles of Port Moller.

Date	Site code	Time	Depth (m)	Temp (degC)	conduct. (mmho/cm)	salinity (ppt)
			MEAN	10.33		23.754
			SD	0.10		0.07
			N	10		10
14-Jun-89	C	1755	0	10.45	27.80	24.41
14-Jun-89	C	1755	2	10.12	27.89	24.62
14-Jun-89	C	1755	4	9.83	27.89	24.98
14-Jun-89	C	1755	6	9.83	27.91	24.86
14-Jun-89	C	1755	8	9.84	27.91	24.98
14-Jun-89	C	1755	10	9.98	27.91	24.84
14-Jun-89	C	1755	12	9.77	27.87	24.88
14-Jun-89	C	1755	14	9.86	27.87	24.94
14-Jun-89	C	1755	16	9.88	27.89	25.05
14-Jun-89	C	1755	18	9.73	27.89	24.92
			MEAN	9.929		24.848
			SD	0.21		0.19
			N	10		10
14-Jun-89	D	1840	0	9.74	27.96	25.10
14-Jun-89	D	1840	2	9.73	28.01	25.15
14-Jun-89	D	1840	4	9.65	28.01	25.20
14-Jun-89	D	1840	6	9.73	28.02	25.32
14-Jun-89	D	1840	8	9.72	28.04	25.20
14-Jun-89	D	1840	10	9.60	28.04	25.29
14-Jun-89	D	1840	12	9.72	28.04	25.14
14-Jun-89	D	1840	14	9.63	28.04	25.17
14-Jun-89	D	1840	16	9.63	28.04	25.16
14-Jun-89	D	1840	18	9.77	28.04	25.19
14-Jun-89	D	1840	20	9.64	28.04	25.21
14-Jun-89	D	1840	22	9.64	28.04	25.33
14-Jun-89	D	1840	24	9.67	28.04	25.16
			MEAN	9.682		25.202
			SD	0.05		0.07
			N	13		13

Notes:
1. All measurements made with a conductivity-temperature-salinity meter.
2. Dashes indicate no measurements made.

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
11-Jun-89	1	D	2	5	1	7.0	8.1
11-Jun-89	1	D	2	9	2	7.2	8.3
11-Jun-89	1	D	2	61	1	7.3	8.4
11-Jun-89	1	D	2	44	2	7.3	8.4
11-Jun-89	1	D	2	27	1	7.3	8.4
11-Jun-89	1	D	2	15	1	7.5	8.5
11-Jun-89	1	D	2	23	1	7.5	8.5
11-Jun-89	1	D	2	60	1	7.6	8.6
11-Jun-89	1	D	2	52	1	7.6	8.6
11-Jun-89	1	D	2	2	1	7.6	8.6
11-Jun-89	1	D	2	47	1	7.8	8.8
11-Jun-89	1	D	2	48	2	7.8	8.8
11-Jun-89	1	D	2	43	2	7.9	8.9
11-Jun-89	1	D	2	49	2	7.9	8.9
11-Jun-89	1	D	2	57	1	7.9	8.9
11-Jun-89	1	D	2	62	2	8.1	9.0
11-Jun-89	1	D	2	10	1	8.1	9.0
11-Jun-89	1	D	2	28	1	8.1	9.0
11-Jun-89	1	D	2	14	1	8.1	9.0
11-Jun-89	1	D	2	30	1	8.1	9.0
11-Jun-89	1	D	2	54	1	8.2	9.1
11-Jun-89	1	D	2	36	1	8.2	9.1
11-Jun-89	1	D	2	12	2	8.2	9.1
11-Jun-89	1	D	2	46	2	8.2	9.1
11-Jun-89	1	D	2	37	2	8.4	9.3
11-Jun-89	1	D	2	59	2	8.4	9.3
11-Jun-89	1	D	2	41	2	8.4	9,3
11-Jun-89	1	D	2	32	2	8.5	9.4
11-Jun-89	1	D	2	19	2	8.5	9.4
11-Jun-89	1.	D	2	34	2	8.5	9.4
11-Jun-89	1	D	2	17	2	8.5	9.4
11-Jun-89	1	D	2	25	2	8.5	9.4
11-Jun-89	1	D	2	50	2	8.7	9.6
11-Jun-89	1	D	2	56	2	8.7	9.6
11-Jun-89	1	D	2	38	2	8.7	9.6

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
11-Jun-89	1	D	2	8	2	8.7	9.6
11-Jun-89	1	D	2	26	2	8.8	9.7
11-Jun-89	1	D	2	45	2	8.8	9.7
11-Jun-89	1	D	2	7	2	9.0	9.8
11-Jun-89	1	D	2	40	2	9.0	9.8
11-Jun-89	1	D	2	21	2	9.0	9.8
11-Jun-89	1	D	2	35	2	9.0	9.8
11-Jun-89	1	D	2	18	2	9.1	9.9
11-Jun-89	1	D	2	1	2	9.1	9.9
11-Jun-89	1	D	2	58	2	9.1	9.9
11-Jun-89	1	D	2	39	2	9.1	9.9
11-Jun-89	1	D	2	53	2	9.1	9.9
11-Jun-89	1	D	2	11	2	9.3	10.1
11-Jun-89	1	D	2	16	1	9.3	10.1
11-Jun-89	1	D	2	22	2	9.3	10.1
11-Jun-89	1	D	2	4	2	9.4	10.2
11-Jun-89	1	D	2	31	2	9.4	10.2
11-Jun-89	1	D	2	29	2	9.6	10.3
11-Jun-89	1	D	2	24	2	9.6	10.3
11-Jun-89	1	D	2	3	2	9.6	10.3
11-Jun-89	1	D	2	20	2	9.6	10.3
11-Jun-89	1	D	2	51	2	9.6	10.3
11-Jun-89	1	D	2	55	2	9.7	10.4
11-Jun-89	1	D	2	63	2	9.9	10.6
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					MEAN	8.5	9.4
					SD	0.7	0.6
					N	59	59
11-Jun-89	1.	D	1	13	2	11.2	11.8
11-Jun-89	1	D	1	42	2	11.2	11.8
11-Jun-89	1	D	1	6	2	11.5	12.0
11-Jun-89	1	D	1	33	2	11.8	12.3
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					MEAN	11.4	12.0

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
					SD	0.3	0.3
					N	4	4
11-Jun-89	2	D	2	58	1	6.7	7.9
11-Jun-89	2	D	2	15	2	7.2	8.3
11-Jun-89	2	D	2	96	1	7.3	8.4
11-Jun-89	2	D	2	48	2	7.3	8.4
11-Jun-89	2	D	2	75	2	7.3	8.4
11-Jun-89	2	D	2	66	1	7.3	8.4
11-Jun-89	2	D	2	18	2	7.5	8.5
11-Jun-89	2	D	2	11	2	7.5	8.5
11-Jun-89	2	D	2	22	1	7.5	8.5
11-Jun-89	2	D	2	36	1	7.5	8.5
11-Jun-89	2	D	2	67	2	7.5	8.5
11-Jun-89	2	D	2	78	2	7.5	8.5
11-Jun-89	2	D	2	74	2	7.5	8.5
11-Jun-89	2	D	2	69	1	7.6	8.6
11-Jun-89	2	D	2	60	2	7.6	8.6
11-Jun-89	2	D	2	52	1	7.6	8.6
11-Jun-89	2	D	2	82	1	7.6	8.6
11-Jun-89	2	D	2	100	1	7.6	8.6
11-Jun-89	2	D	2	7	1	7.6	8.6
11-Jun-89	2	D	2	90	1	7.8	8.8
11-Jun-89	2	D	2	99	1	7.8	8.8
11-Jun-89	2	D	2	42	1	7.8	8.8
11-Jun-89	2	D	2	63	2	7.8	8.8
11-Jun-89	2	D	2	14	1	7.9	8.9
11-Jun-89	2	D	2	45	2	7.9	8.9
11-Jun-89	2	D	2	13	1	7.9	8.9
11-Jun-89	2.	D	2	88	2	7.9	8.9
11-Jun-89	2	D	2	93	2	7.9	8.9
11-Jun-89	2	D	2	53	1	7.9	8.9
11-Jun-89	2	D	2	64	1	7.9	8.9
11-Jun-89	2	D	2	38	1	7.9	8.9
11-Jun-89	2	D	2	51	2	8.1	9.0

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
11-Jun-89	2	D	2	19	1	8.1	9.0
11-Jun-89	2	D	2	33	2	8.1	9.0
11-Jun-89	2	D	2	54	1	8.1	9.0
11-Jun-89	2	D	2	43	2	8.1	9.0
11-Jun-89	2	D	2	40	2	8.1	9.0
11-Jun-89	2	D	2	16	1	8.1	9.0
11-Jun-89	2	D	2	1	1	8.1	9.0
11-Jun-89	2	D	2	31	1	8.1	9.0
11-Jun-89	2	D	2	92	1	8.1	9.0
11-Jun-89	2	D	2	3	2	8.2	9.1
11-Jun-89	2	D	2	9	2	8.2	9.1
11-Jun-89	2	D	2	94	2	8.2	9.1
11-Jun-89	2	D	2	25	1	8.2	9.1
11-Jun-89	2	D	2	23	2	8.2	9.1
11-Jun-89	2	D	2	5	2	8.2	9.1
11-Jun-89	2	D	2	32	1	8.2	9.1
11-Jun-89	2	D	2	49	2	8.4	9.3
11-Jun-89	2	D	2	46	2	8.4	9.3
11-Jun-89	2	D	2	6	2	8.4	9.3
11-Jun-89	2	D	2	95	1	8.4	9.3
11-Jun-89	2	D	2	98	2	8.4	9.3
11-Jun-89	2	D	2	10	2	8.4	9.3
11-Jun-89	2	D	2	89	2	8.4	9.3
11-Jun-89	2	D	2	8	2	8.4	9.3
11-Jun-89	2	D	2	29	1	8.5	9.4
11-Jun-89	2	D	2	2	2	8.5	9.4
11-Jun-89	2	D	2	65	2	8.5	9.4
11-Jun-89	2	D	2	39	2	8.5	9.4
11-Jun-89	2	D	2	34	2	8.5	9.4
11-Jun-89	2.	D	2	26	2	8.5	9.4
11-Jun-89	2	D	2	97	2	8.7	9.6
11-Jun-89	2	D	2	84	2	8.7	9.6
11-Jun-89	2	D	2	87	2	8.7	9.6
11-Jun-89	2	D	2	41	2	8.7	9.6
11-Jun-89	2	D	2	83	2	8.7	9.6

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
11-Jun-89	2	D	2	20	2	8.7	9.6
11-Jun-89	2	D	2	80	2	8.7	9.6
11-Jun-89	2	D	2	70	2	8.8	9.7
11-Jun-89	2	D	2	35	2	8.8	9.7
11-Jun-89	2	D	2	50	2	8.8	9.7
11-Jun-89	2	D	2	73	2	8.8	9.7
11-Jun-89	2	D	2	86	2	8.8	9.7
11-Jun-89	2	D	2	91	2	8.8	9.7
11-Jun-89	2	D	2	62	2	9.0	9.8
11-Jun-89	2	D	2	71	2	9.0	9.8
11-Jun-89	2	D	2	24	2	9.0	9.8
11-Jun-89	2	D	2	55	2	9.0	9.8
11-Jun-89	2	D	2	85	2	9.0	9.8
11-Jun-89	2	D	2	17	2	9.0	9.8
11-Jun-89	2	D	2	4	2	9.1	9.9
11-Jun-89	2	D	2	2a	2	9.1	9.9
11-Jun-89	2	D	2	47	2	9.1	9.9
11-Jun-89	2	D	2	79	2	9.1	9.9
11-Jun-89	2	D	2	77	2	9.1	9.9
11-Jun-89	2	D	2	72	2	9.1	9.9
11-Jun-89	2	D	2	44	2	9.3	10.1
11-Jun-89	2	D	2	68	2	9.4	10.2
11-Jun-89	2	D	2	81	2	9.4	10.2
11-Jun-89	2	D	2	57	2	9.4	10.2
11-Jun-89	2	D	2	37	2	9.4	10.2
11-Jun-89	2	D	2	12	2	9.4	10.2
11-Jun-89	2	D	2	21	2	9.4	10.2
11-Jun-89	2	D	2	30	2	9.4	10.2
11-Jun-89	2	D	2	56	2	9.4	10.2
11-Jun-89	2.	D	2	61	2	9.6	10.3
11-Jun-89	2	D	2	76	2	9.7	10.4
11-Jun-89	2	D	2	27	2	9.7	10.4
						--------------	--------------
					MEAN	8.4	9.3
					SD	0.7	0.6

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
					N	99	99
11-Jun-89	2	D	1	59	2	10.2	10.9
					---	-----------	--------------
					MEAN	10.2	10.9
					SD		
					N	1	1
11-Jun-89	3	A	2	61	2	6.1	7.3
11-Jun-89	3	A	2	97	1	6.1	7.3
11-Jun-89	3	A	2	9	1	6.3	7.5
11-Jun-89	3	A	2	75	2	6.4	7.6
11-Jun-89	3	A	2	99	1	6.7	7.9
11-Jun-89	3	A	2	16	2	6.7	7.9
11-Jun-89	3	A	2	12	1	6.9	8.0
11-Jun-89	3	A	2	39	1	6.9	8.0
11-Jun-89	3	A	2	1	1	6.9	8.0
11-Jun-89	3	A	2	79	1	6.9	8.0
11-Jun-89	3	A	2	98	1	7.0	8.1
11-Jun-89	3	A	2	47	2	7.0	8.1
11-Jun-89	3	A	2	92	1	7.0	8.1
11-Jun-89	3	A	2	87	2	7.0	8.1
11-Jun-89	3	A	2	89	1	7.0	8.1
11-Jun-89	3	A	2	43	1	7.2	8.3
11-Jun-89	3	A	2	52	1	7.2	8.3
11-Jun-89	3	A	2	3	1	7.2	8.3
11-Jun-89	3	A	2	46	1	7.2	8.3
11-Jun-89	3	A	2	81	2	7.2	8.3
11-Jun-89	3	A	2	95	1	7.2	8.3
11-Jun-89	3.	A	2	57	1	7.3	8.4
11-Jun-89	3	A	2	36	2	7.3	8.4
11-Jun-89	3	A	2	91	1	7.3	8.4
11-Jun-89	3	A	2	86	1	7.3	8.4
11-Jun-89	3	A	2	32	1	7.5	8.5
11-Jun-89	3	A	2	100	1	7.5	8.5

Appendix E. Lengths of herring larvae in port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
11-Jun-89	3	A	2	64	2	7.5	8.5
11-Jun-89	3	A	2	41	2	7.5	8.5
11-Jun-89	3	A	2	10	2	7.5	8.5
11-Jun-89	3	A	2	35	1	7.6	8.6
11-Jun-89	3	A	2	54	1	7.6	8.6
11-Jun-89	3	A	2	67	1	7.6	8.6
11-Jun-89	3	A	2	71	2	7.6	8.6
11-Jun-89	3	A	2	13	1	7.6	8.6
11-Jun-89	3	A	2	62	2	7.6	8.6
11-Jun-89	3	A	2	93	1	7.6	8.6
11-Jun-89	3	A	2	70	1	7.6	8.6
11-Jun-89	3	A	2	27	1	7.8	8.8
11-Jun-89	3	A	2	83	2	7.8	8.8
11-Jun-89	3	A	2	88	2	7.8	8.8
11-Jun-89	3	A	2	4	2	7.8	8.8
11-Jun-89	3	A	2	28	2	7.8	8.8
11-Jun-89	3	A	2	49	1	7.8	8.8
11-Jun-89	3	A	2	72	2	7.8	8.8
11-Jun-89	3	A	2	50	2	7.8	8.8
11-Jun-89	3	A	2	31	2	7.8	8.8
11-Jun-89	3	A	2	65	1	7.8	8.8
11-Jun-89	3	A	2	77	2	7.8	8.8
11-Jun-89	3	A	2	2	2	7.8	8.8
11-Jun-89	3	A	2	94	2	7.9	8.9
11-Jun-89	3	A	2	90	2	7.9	8.9
11-Jun-89	3	A	2	20	2	7.9	8.9
11-Jun-89	3	A	2	96	1	7.9	8.9
11-Jun-89	3	A	2	76	2	7.9	8.9
11-Jun-89	3	A	2	7	1	7.9	8.9
11-Jun-89	3.	A	2	21	1	7.9	8.9
11-Jun-89	3	A	2	78	1	7.9	8.9
11-Jun-89	3	A	2	17	2	7.9	8.9
11-Jun-89	3	A	2	18	2	7.9	8.9
11-Jun-89	3	A	2	30	1	8.1	9.0
11-Jun-89	3	A	2	60	2	8.1	9.0

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
11-Jun-89	3	A	2	44	2	8.2	9.1
11-Jun-89	3	A	2	69	2	8.2	9.1
11-Jun-89	3	A	2	24	1	8.2	9.1
11-Jun-89	3	A	2	55	2	8.2	9.1
11-Jun-89	3	A	2	5	2	8.2	9.1
11-Jun-89	3	A	2	66	2	8.2	9.1
11-Jun-89	3	A	2	11	2	8.2	9.1
11-Jun-89	3	A	2	14	2	8.2	9.1
11-Jun-89	3	A	2	25	2	8.4	9.3
11-Jun-89	3	A	2	58	2	8.4	9.3
11-Jun-89	3	A	2	82	2	8.4	9.3
11-Jun-89	3	A	2	38	1	8.4	9.3
11-Jun-89	3	A	2	56	2	8.4	9.3
11-Jun-89	3	A	2	53	2	8.4	9.3
11-Jun-89	3	A	2	84	2	8.5	9.4
11-Jun-89	3	A	2	15	2	8.5	9.4
11-Jun-89	3	A	2	37	2	8.5	9.4
11-Jun-89	3	A	2	80	2	8.7	9.6
11-Jun-89	3	A	2	85	2	8.7	9.6
11-Jun-89	3	A	2	23	2	8.7	9.6
11-Jun-89	3	A	2	45	2	8.7	9.6
11-Jun-89	3	A	2	68	2	8.7	9.6
11-Jun-89	3	A	2	74	2	8.7	9.6
11-Jun-89	3	A	2	51	2	8.8	9.7
11-Jun-89	3	A	2	73	2	9.0	9.8
11-Jun-89	3	A	2	48	2	9.0	9.8
11-Jun-89	3	A	2	63	2	9.3	10.1
11-Jun-89	3	A	2	42	2	9.7	10.4
						--------------	--------------
					MEAN	7.8	8.8
					SD	0.7	0.6
					N	90	90
11-Jun-89	3	A	1	40	2	10.6	11.2
11-Jun-89	3	A	1	29	2	10.8	11.4

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (MM)
1 1-Jun-89	3	A	1	22	2	10.8	11.4
1 1-Jun-89	3	A	1	19	2	11.2	11.8
1 1-Jun-89	3	A	1	26	2	11.7	12.2
1 1-Jun-89	3	A	1	59	2	12.0	12.5
11-Jun-89	3	A	1	33	2	12.1	12.6
11-Jun-89	3	A	1	6	2	12.1	12.6
11-Jun-89	3	A	1	8	2	12.7	13.1
						--------------	--------------
					MEAN	11.6	12.1
					SD	0.7	0.7
					N	9	9
11-Jun-89	4	F	2	4	1	7.6	8.6
11-Jun-89	4	F	2	5	2	7.8	8.8
11-Jun-89	4	F	2	2	2	8.7	9.6
11-Jun-89	4	F	2	6	2	9.1	9.9
11-Jun-89	4	F	2	3	2	9.1	9.9
11-Jun-89	4	F	2	7	2	9.6	10.3
1 1-Jun-89	4	F	2	8	2	9.7	10.4
11-Jun-89	4	F	2	1	2	9.9	10.6
						--------------	--------------
					MEAN	8.9	9.8
					SD	0.9	0.7
					N	8	8
			2	GRAND	MEAN	8.3	9.2
					SD	0.7	0.6
					N	256	256
			1	GRAND	MEAN	11.4	12.0
					SD	0.7	0.6
					N	14	14
12-Jun-89	5	H	2	1	2	9.4	10.2
						--------------	--------------

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
					MEAN	9.4	10.2
					SD		
					N	1	1
12-Jun-89	6	I	-				
12-Jun-89	7	G	-				
12-Jun-89	8	K	2	3	1	7.0	8.1
12-Jun-89	8	K	2	1	1	8.1	9.0
12-Jun-89	8	K	2	2	2	8.2	9.1
						--------------	--------_-----
					MEAN	7.8	8.8
					SD	0.7	0.6
					N	3	3
12-Jun-89	9	0	2	37	2	6.7	7.9
12-Jun-89	9	0	2	74	2	6.9	8.0
12-Jun-89	9	0	2	62	2	7.2	8.3
12-Jun-89	9	0	2	58	2	7.3	8.4
12-Jun-89	9	0	2	46	2	7.3	8.4
12-Jun-89	9	0	2	87	2	7.3	8.4
12-Jun-89	9	0	2	70	2	7.5	8.5
12-Jun-89	9	0	2	32	1	7.5	8.5
12-Jun-89	9	0	2	83	1	7.5	8.5
12-Jun-89	9	0	2	36	2	7.5	8.5
12-Jun-89	9	0	2	6	1	7.5	8.5
12-Jun-89	9	0	2	54	2	7.5	8.5
12-Jun-89	9	0	2	96	1	7.5	8.5
12-Jun-89	9.	0	2	27	2	7.5	8.5
12-Jun-89	9	0	2	89	2	7.6	8.6
12-Jun-89	9	0	2	52	2	7.6	8.6
12-Jun-89	9	0	2	11	1	7.6	8.6
12-Jun-89	9	0	2	34	2	7.6	8.6
12-Jun-89	9	0	2	39	2	7.6	8.6

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
12-Jun-89	9	0	2	24	2	7.6	8.6
12-Jun-89	9	0	2	21	2	7.6	8.6
12-Jun-89	9	0	2	23	2	7.8	8.8
12-Jun-89	9	0	2	14	1	7.8	8.8
12-Jun-89	9	0	2	65	1	7.8	8.8
12-Jun-89	9	0	2	15	2	7.8	8.8
12-Jun-89	9	0	2	29	2	7.8	8.8
12-Jun-89	9	0	2	5	2	7.8	8.8
12-Jun-89	9	0	2	69	1	7.8	8.8
12-Jun-89	9	0	2	100	2	7.8	8.8
12-Jun-89	9	0	2	47	2	7.8	8.8
12-Jun-89	9	0	2	67	2	7.9	8.9
12-Jun-89	9	0	2	13	2	7.9	8.9
12-Jun-89	9	0	2	31	1	7.9	8.9
12-Jun-89	9	0	2	95	2	7.9	8.9
12-Jun-89	9	0	2	72	1	‘7.9	8.9
12-Jun-89	9	0	2	28	2	7.9	8.9
12-Jun-89	9	0	2	17	2	7.9	8.9
12-Jun-89	9	0	2	63	2	7.9	8.9
12-Jun-89	9	0	2	82	2	8.1	9.0
12-Jun-89	9	0	2	25	2	8.1	9.0
12-Jun-89	9	0	2	91	2	8.1	9.0
12-Jun-89	9	0	2	84	2	8.1	9.0
12-Jun-89	9	0	2	90	2	8.1	9.0
12-Jun-89	9	0	2	68	2	8.1	9.0
12-Jun-89	9	0	2	51	2	8.2	9.1
12-Jun-89	9	0	2	26	2	8.2	9.1
12-Jun-89	9	0	2	18	2	8.2	9.1
12-Jun-89	9	0	2	8	2	8.2	9.1
12-Jun-89	9-	0	2	71	2	8.2	9.1
12-Jun-89	9	0	2	80	2	8.2	9.1
12-Jun-89	9	0	2	50	2	8.2	9.1
12-Jun-89	9	0	2	56	2	8.2	9.1
12-Jun-89	9	0	2	43	2	8.2	9.1
12-Jun-89	9	0	2	57	2	8.2	9.1

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
12-Jun-89	9	0	2	45	2	8.2	9.1
12-Jun-89	9	0	2	44	2	8.2	9.1
12-Jun-89	9	0	2	99	2	8.2	9.1
12-Jun-89	9	0	2	41	2	8.2	9.1
12-Jun-89	9	0	2	97	2	8.4	9.3
12-Jun-89	9	0	2	78	2	8.4	9.3
12-Jun-89	9	0	2	88	2	8.4	9.3
12-Jun-89	9	O	2	92	2	8.4	9.3
12-Jun-89	9	0	2	7	2	8.4	9.3
12-Jun-89	9	0	2	38	2	8.4	9.3
12-Jun-89	9	0	2	53	2	8.4	9.3
12-Jun-89	9	0	2	35	2	8.4	9.3
12-Jun-89	9	0	2	49	2	8.4	9.3
12-Jun-89	9	0	2	81	2	8.4	9.3
12-Jun-89	9	0	2	4	2	8.4	9.3
12-Jun-89	9	0	2	9	2	8.4	9.3
12-Jun-89	9	0	2	86	2	8.4	9.3
12-Jun-89	9	0	2	93	2	8.5	9.4
12-Jun-89	9	0	2	16	2	8.5	9.4
12-Jun-89	9	0	2	94	2	8.5	9.4
12-Jun-89	9	0	2	75	2	8.5	9.4
12-Jun-89	9	0	2	30	2	8.5	9.4
12-Jun-89	9	0	2	40	2	8.5	9.4
12-Jun-89	9	0	2	64	2	8.7	9.6
12-Jun-89	9	0	2	76	2	8.7	9.6
12-Jun-89	9	0	2	55	2	8.7	9.6
12-Jun-89	9	0	2	22	2	8.7	9.6
12-Jun-89	9	0	2	42	2	8.7	9.6
12-Jun-89	9	0	2	61	2	8.7'	9.6
12-Jun-89	9.	0	2	10	2	8.7	9.6
12-Jun-89	9	0	2	79	2	8.7	9.6
12-Jun-89	9	0	2	2	2	8.7	9.6
12-Jun-89	9	0	2	73	2	8.8	9.7
12-Jun-89	9	0	2	85	2	8.8	9.7
12-Jun-89	9	0	2	60	2	8.8	9.7

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
12-Jun-89	9	0	2	3	2	9.0	9.8
12-Jun-89	9	0	2	59	2	9.0	9.8
12-Jun-89	9	0	2	98	2	9.0	9.8
12-Jun-89	9	0	2	33	2	9.0	9.8
12-Jun-89	9	0	2	66	2	9.1	9.9
12-Jun-89	9	0	2	48	2	9.1	9.9
12-Jun-89	9	0	2	19	2	9.1	9.9
12-Jun-89	9	0	2	77	2	9.1	9.9
12-Jun-89	9	0	2	12	2	9.3	10.1
12-Jun-89	9	0	2	20	2	9.3	10.1
12-Jun-89	9	0	2	1	2	9.4	10.2
						--------------	--------------
					MEAN	8.2	9.1
					SD	0.6	0.5
					N	100	100
12-Jun-89	10	M	2	15	2	6.9	8.0
12-Jun-89	10	M	2	16	1	6.9	8.0
12-Jun-89	10	M	2	14	1	6.9	8.0
12-Jun-89	10	M	2	74	1	6.9	8.0
12-Jun-89	10	M	2	70	1	6.9	8.0
12-Jun-89	10	M	2	53	1	6.9	8.0
12-Jun-89	10	M	2	40	1	6.9	8.0
12-Jun-89	10	M	2	54	2	6.9	8.0
12-Jun-89	10	M	2	75	1	6.9	8.0
12-Jun-89	10	M	2	30	1	7.0	8.1
12-Jun-89	10	M	2	7	1	7.0	8.1
12-Jun-89	10	M	2	26	2	7.0	8.1
12-Jun-89	10	M	2	81	1	7.0	8.1
12-Jun-89	10	M	2	1	2	7.0	8.1
12-Jun-89	10	M	2	44	1	7.0	8.1
12-Jun-89	10	M	2	47	1	7.0	8.1
12-Jun-89	10	M	2	79	1	7.2	8.3
12-Jun-89	10	M	2	3	1	7.2	8.3
12-Jun-89	10	M	2	68	1	7.2	8.3

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
12-Jun-89	10	M	2	11	2	7.2	8.3
12-Jun-89	10	M	2	24	1	7.2	8.3
12-Jun-89	10	M	2	63	1	7.2	8.3
12-Jun-89	10	M	2	80	1	7.2	8.3
12-Jun-89	10	M	2	61	1	7.2	8.3
12-Jun-89	10	M	2	28	1	7.2	8.3
12-Jun-89	10	M	2	8’7	1	7.3	8.4
12-Jun-89	10	M	2	38	1	7.3	8.4
12-Jun-89	10	M	2	8	1	7.3	8.4
12-Jun-89	10	M	2	51	2	7.5	8.5
12-Jun-89	10	M	2	62	2	7.5	8.5
12-Jun-89	10	M	2	46	1	7.5	8.5
12-Jun-89	10	M	2	60	1	7.5	8.5
12-Jun-89	10	M	2	77	2	7.5	8.5
12-Jun-89	10	M	2	39	1	7.5	8.5
12-Jun-89	10	M	2	10	1	7.5	8.5
12-Jun-89	10	M	2	20	1	7.5	8.5
12-Jun-89	10	M	2	64	1	7.5	8.5
12-Jun-89	10	M	2	49	1	7.5	8.5
12-Jun-89	10	M	2	76	2	7.5	8.5
12-Jun-89	10	M	2	94	1	7.5	8.5
12-Jun-89	10	M	2	71	1	7.5	8.5
12-Jun-89	10	M	2	22	1	7.5	8.5
12-Jun-89	10	M	2	65	1	7.6	8.6
12-Jun-89	10	M	2	36	1	7.6	8.6
12-Jun-89	10	M	2	35	2	7.6	8.6
12-Jun-89	10	M	2	89	1	7.6	8.6
12-Jun-89	10	M	2	98	1	7.6	8.6
12-Jun-89	10	M	2	17	1	7.6	8.6
12-Jun-89	10	M	2	48	1	7.6	8.6
12-Jun-89	10	M	2	19	1	7.6	8.6
12-Jun-89	10	M	2	33	1	7.6	8.6
12-Jun-89	10	M	2	18	1	7.6	8.6
12-Jun-89	10	M	2	23	1	7.6	8.6
12-Jun-89	10	M	2	99	2	7.6	8.6

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
12-Jun-89	10	M	2	73	2	7.6	8.6
12-Jun-89	10	M	2	2	1	7.6	8.6
12-Jun-89	10	M	2	58	1	7.8	8.8
12-Jun-89	10	M	2	32	1	7.8	8.8
12-Jun-89	10	M	2	84	2	7.8	8.8
12-Jun-89	10	M	2	50	1	7.8	8.8
12-Jun-89	10	M	2	4	2	7.8	8.8
12-Jun-89	10	M	2	67	1	7.8	8.8
12-Jun-89	10	M	2	69	1	7.8	8.8
12-Jun-89	10	M	2	97	2	7.8	8.8
12-Jun-89	10	M	2	83	1	7.8	8.8
12-Jun-89	10	M	2	6	1	7.9	8.9
12-Jun-89	10	M	2	55	1	7.9	8.9
12-Jun-89	10	‘M	2	31	1	7.9	8.9
12-Jun-89	10	M	2	88	1	7.9	8.9
12-Jun-89	10	M	2	93	1	7.9	8.9
12-Jun-89	10	M	2	72	1	8.1	9.0
12-Jun-89	10	M	2	86	1	8.1	9.0
12-Jun-89	10	M	2	57	1	8.1	9.0
12-Jun-89	10	M	2	27	1	8.1	9.0
12-Jun-89	10	M	2	42	1	8.1	9.0
12-Jun-89	10	M	2	34	1	8.1	9.0
12-Jun-89	10	M	2	29	1	8.1	9.0
12-Jun-89	10	M	2	56	2	8.2	9.1
12-Jun-89	10	M	2	92	2	8.2	9.1
12-Jun-89	10	M	2	12	2	8.2	9.1
12-Jun-89	10	M	2	66	2	8.2	9.1
12-Jun-89	10	M	2	78	2	8.2	9.1
12-Jun-89	10	M	2	5	1	8.2	9.1
12-Jun-89	10	M	2	41	2	8.2	9.1
12-Jun-89	10	M	2	52	1	8.2	9.1
12-Jun-89	10	M	2	90	1	8.4	9.3
12-Jun-89	10	M	2	43	2	8.4	9.3
12-Jun-89	10	M	2	100	2	8.4	9.3
12-Jun-89	10	M	2	82	2	8.5	9.4

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
12-Jun-89	10	M	2	13	2	8.5	9.4
12-Jun-89	10	M	2	37	2	8.5	9.4
12-Jun-89	10	M	2	91	1	8.5	9.4
12-Jun-89	10	M	2	9	2	8.5	9.4
12-Jun-89	10	M	2	45	2	8.7	9.6
12-Jun-89	10	M	2	59	2	8.7	9.6
12-Jun-89	10	M	2	25	2	8.7	9.6
12-Jun-89	10	M	2	85	2	8.7	9.6
12-Jun-89	10	M	2	95	2	8.8	9.7
12-Jun-89	10	M	2	96	2	9.0	9.8
12-Jun-89	10	M	2	21	2	9.1	9.9
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					MEAN	7.7	8.7
					SD	0.5	0.5
					N	100	100
			2 GRAND		MEAN	7.9	8.9
					SD	0.6	0.5
					N	204	204
			1 GRAND		MEAN		
					SD		
					N		
13-Jun-89	11	D	2	91	2	7.2	8.3
13-Jun-89	11	D	2	63	1	7.3	8.4
13-Jun-89	11	D	2	95	2	7.3	8.4
13-Jun-89	11	D	2	51	1	7.5	8.5
13-Jun-89	11	D	2	32	1	7.5	8.5
13-Jun-89	11	D	2	41	2	7.5	8.5
13-Jun-89	11	D	2	36	1	7.5	8.5
13-Jun-89	11	D	2	49	2	7.5	8.5
13-Jun-89	11	D	2	87	1	7.5	8.5
13-Jun-89	11	D	2	10	1	7.5	8.5
13-Jun-89	11	D	2	79	2	7.5	8.5

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
13-Jun-89	11	D	2	60	2	7.5	8.5
13-Jun-89	11	D	2	7	2	7.6	8.6
13-Jun-89	11	D	2	78	1	7.6	8.6
13-Jun-89	11	D	2	13	2	7.6	8.6
13-Jun-89	11	D	2	9	2	7.6	8.6
13-Jun-89	11	D	2	20	2	7.6	8.6
13-Jun-89	11	D	2	82	1	7.6	8.6
13-Jun-89	11	D	2	45	2	7.6	8.6
13-Jun-89	11	D	2	56	2	7.6	8.6
13-Jun-89	11	D	2	26	1	7.6	8.6
13-Jun-89	11	D	2	15	1	7.8	8.8
13-Jun-89	11	D	2	46	1	7.8	8.8
13-Jun-89	11	D	2	94	2	7.8	8.8
13-Jun-89	11	D	2	31	2	7.8	8.8
13-Jun-89	11	D	2	24	2	7.8	8.8
13-Jun-89	11	D	2	35	2	7.8	8.8
13-Jun-89	11	D	2	33	1	7.9	8.9
13-Jun-89	11	D	2	44	1	7.9	8.9
13-Jun-89	11	D	2	21	2	7.9	8.9
13-Jun-89	11	D	2	74	2	7.9	8.9
13-Jun-89	11	D	2	25	1	7.9	8.9
13-Jun-89	11	D	2	89	1	7.9	8.9
13-Jun-89	11	D	2	54	2	7.9	8.9
13-Jun-89	11	D	2	6'7	1	7.9	8.9
13-Jun-89	11	D	2	40	1	7.9	8.9
13-Jun-89	11	D	2	42	2	7.9	8.9
13-Jun-89	11	D	2	16	2	8.1	9.0
13-Jun-89	11	D	2	98	1	8.1	9.0
13-Jun-89	11	D	2	71	1	8.1	9.0
13-Jun-89	11	D	2	38	2	8.1	9.0
13-Jun-89	11	D	2	52	2	8.1	9.0
13-Jun-89	11	D	2	37	2	8.1	9.0
13-Jun-89	11	D	2	50	1	8.1	9.0
13-Jun-89	11	D	2	39	2	8.1	9.0
13-Jun-89	11	D	2	84	1	8.1	9.0

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
13-Jun-89	11	D	2	93	2	8.1	9.0
13-Jun-89	11	D	2	48	1	8.1	9.0
13-Jun-89	11	D	2	2	1	8.2	9.1
13-Jun-89	11	D	2	83	2	8.2	9.1
13-Jun-89	11	D	2	76	1	8.2	9.1
13-Jun-89	11	D	2	80	1	8.2	9.1
13-Jun-89	11	D	2	14	2	8.2	9.1
13-Jun-89	11	D	2	69	1	8.2	9.1
13-Jun-89	11	D	2	6	1	8.2	9.1
13-Jun-89	11	D	2	72	1	8.2	9.1
13-Jun-89	11	D	2	88	2	8.2	9.1
13-Jun-89	11	D	2	43	1	8.2	9.1
13-Jun-89	11	D	2	53	1	8.4	9.3
13-Jun-89	11	D	2	3	1	8.4	9.3
13-Jun-89	11	D	2	70	2	8.4	9.3
13-Jun-89	11	D	2	68	2	8.4	9.3
13-Jun-89	11	D	2	73	1	8.4	9.3
13-Jun-89	11	D	2	34	1	8.4	9.3
13-Jun-89	11	D	2	64	2	8.4	9.3
13-Jun-89	11	D	2	62	1	8.4	9.3
13-Jun-89	11	D	2	59	1	8.4	9.3
13-Jun-89	11	D	2	55	1	8.4	9.3
13-Jun-89	11	D	2	4	1	8.4	9.3
13-Jun-89	11	D	2	58	1	8.4	9.3
13-Jun-89	11	D	2	97	1	8.4	9.3
13-Jun-89	11	D	2	1	2	8.4	9.3
13-Jun-89	11	D	2	61	2	8.5	9.4
13-Jun-89	11	D	2	81	2	8.5	9.4
13-Jun-89	11	D	2	28	2	8.5	9.4
13-Jun-89	11	D	2	85	1	8.5	9.4
13-Jun-89	11	D	2	12	1	8.5	9.4
13-Jun-89	11	D	2	29	1	8.7	9.6
13-Jun-89	11	D	2	27	2	8.7	9.6
13-Jun-89	11	D	2	17	2	8.7	9.6
13-Jun-89	11	D	2	77	2	8.7	9.6

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
13-Jun-89	11	D	2	57	2	8.7	9.6
13-Jun-89	11	D	2	96	2	8.7	9.6
13-Jun-89	11	D	2	8	1	8.7	9.6
13-Jun-89	11	D	2	19	1	8.7	9.6
13-Jun-89	11	D	2	30	1	8.7	9.6
13-Jun-89	11	D	2	90	2	8.8	9.7
13-Jun-89	11	D	2	66	1	8.8	9.7
13-Jun-89	11	D	2	100	1	8.8	9.7
13-Jun-89	11	D	2	18	2	8.8	9.7
13-Jun-89	11	D	2	99	1	9.0	9.8
13-Jun-89	11	D	2	47	1	9.0	9.8
13-Jun-89	11	D	2	75	2	9.0	9.8
13-Jun-89	11	D	2	92	2	9.0	9.8
13-Jun-89	11	D	2	86	2	9.0	9.8
13-Jun-89	11	D	2	11	2	9.1	9.9
13-Jun-89	11	D	2	22	2	9.1	9.9
13-Jun-89	11	D	2	23	2	9.4	10.2
13-Jun-89	11	D	2	5	2	9.7	10.4
13-Jun-89	11	D	2	65	2	9.9	10.6
					MEAN	8.2	9.1
					SD	0.5	0.5
					N	100	100
13-Jun-89	12	c	2	59	2	6.4	7.6
13-Jun-89	12	c	2	51	2	6.7	7.9
13-Jun-89	12	c	2	17	1	7.0	8.1
13-Jun-89	12	c	2	73	1	7.3	8.4
13-Jun-89	12	c	2	10	2	7.3	8.4
13-Jun-89	12	c	2	14	1	7.6	8.6
13-Jun-89	12	c	2	40	1	7.6	8.6
13-Jun-89	12	c	2	6	1	7.6	8.6
13-Jun-89	12	c	2	46	2	7.6	8.6
13-Jun-89	12	c	2	64	2	7.8	8.8
13-Jun-89	12	c	2	69	2	7.8	8.8

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
13-Jun-89	12	c	2	3	1	7.8	8.8
13-Jun-89	12	c	2	35	2	7.8	8.8
13-Jun-89	12	c	2	98	2	7.8	8.8
13-Jun-89	12	c	2	19	2	7.9	8.9
13-Jun-89	12	c	2	99	1	7.9	8.9
13-Jun-89	12	c	2	1	2	7.9	8.9
13-Jun-89	12	c	2	83	2	7.9	8.9
13-Jun-89	12	c	2	41	2	7.9	8.9
13-Jun-89	12	c	2	49	2	7.9	8.9
13-Jun-89	12	c	2	48	2	8.1	9.0
13-Jun-89	12	c	2	20	1	8.1	9.0
13-Jun-89	12	c	2	90	2	8.1	9.0
13-Jun-89	12	c	2	4	2	8.1	9.0
13-Jun-89	12	c	2	44	1	8.1	9.0
13-Jun-89	12	c	2	96	2	8.1	9.0
13-Jun-89	12	c	2	77	1	8.1	9.0
13-Jun-89	12	c	2	74	2	8.2	9.1
13-Jun-89	12	c	2	25	2	8.2	9.1
13-Jun-89	12	c	2	24	1	8.2	9.1
13-Jun-89	12	c	2	31	2	8.2	9.1
13-Jun-89	12	c	2	70	2	8.2	9.1
13-Jun-89	12	c	2	86	2	8.2	9.1
13-Jun-89	12	c	2	58	2	8.2	9.1
13-Jun-89	12	c	2	30	2	8.2	9.1
13-Jun-89	12	c	2	27	2	8.2	9.1
13-Jun-89	12	c	2	63	2	8.2	9.1
13-Jun-89	12	c	2	2	2	8.2	9.1
13-Jun-89	12	c	2	29	1	8.4	9.3
13-Jun-89	12	c	2	22	2	8.4	9.3
13-Jun-89	12	c	2	72	2	8.4	9.3
13-Jun-89	12	c	2	80	1	8.4	9.3
13-Jun-89	12	c	2	43	2	8.4	9.3
13-Jun-89	12	c	2	18	2	8.4	9.3
13-Jun-89	12	c	2	28	2	8.4	9.3
13-Jun-89	12	c	2	12	2	8.4	9.3

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
13-Jun-89	12	c	2	60	2	8.4	9.3
13-Jun-89	12	c	2	9	1	8.4	9.3
13-Jun-89	12	c	2	54	1	8.4	9.3
13-Jun-89	12	c	2	34	2	8.4	9.3
13-Jun-89	12	c	2	76	2	8.4	9.3
13-Jun-89	12	c	2	7	2	8.4	9.3
13-Jun-89	12	c	2	52	2	8.5	9.4
13-Jun-89	12	c	2	82	2	8.5	9.4
13-Jun-89	12	c	2	21	2	8.5	9.4
13-Jun-89	12	c	2	5	1	8.5	9.4
13-Jun-89	12	c	2	65	2	8.5	9.4
13-Jun-89	12	c	2	53	2	8.5	9.4
13-Jun-89	12	c	2	66	2	8.5	9.4
13-Jun-89	12	c	2	84	2	8.5	9.4
13-Jun-89	12	c	2	67	2	8.5	9.4
13-Jun-89	12	c	2	62	1	8.5	9.4
13-Jun-89	12	c	2	39	1	8.5	9.4
13-Jun-89	12	c	2	95	1	8.5	9.4
13-Jun-89	12	c	2	26	2	8.5	9.4
13-Jun-89	12	c	2	61	2	8.5	9.4
13-Jun-89	12	c	2	13	1	8.5	9.4
13-Jun-89	12	c	2	71	2	8.5	9.4
13-Jun-89	12	c	2	32	2	8.5	9.4
13-Jun-89	12	c	2	78	2	8.7	9.6
13-Jun-89	12	c	2	45	2	8.7	9.6
13-Jun-89	12	c	2	88	2	8.7	9.6
13-Jun-89	12	c	2	100	1	8.7	9.6
13-Jun-89	12	c	2	79	2	8.7	9.6
13-Jun-89	12	c	2	75	2	8.7	9.6
13-Jun-89	12	c	2	94	2	8.7	9.6
13-Jun-89	12	c	2	89	2	8.7	9.6
13-Jun-89	12	c	2	38	2	8.7	9.6
13-Jun-89	12	c	2	93	2	8.7	9.6
13-Jun-89	12	c	2	81	2	8.7	9.6
13-Jun-89	12	c	2	16	2	8.8	9.7

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
13-Jun-89	12	c	2	11	2	8.8	9.7
13-Jun-89	12	c	2	92	2	8.8	9.7
13-Jun-89	12	c	2	47	2	8.8	9.7
13-Jun-89	12	c	2	85	2	8.8	9.7
13-Jun-89	12	c	2	36	2	8.8	9.7
13-Jun-89	12	c	2	8	1	8.8	9.7
13-Jun-89	12	c	2	87	2	8.8	9.7
13-Jun-89	12	c	2	50	2	8.8	9.7
13-Jun-89	12	c	2	23	2	9.0	9.8
13-Jun-89	12	c	2	15	2	9.1	9.9
13-Jun-89	12	c	2	37	1	9.1	9.9
13-Jun-89	12	c	2	97	2	9.3	10.1
13-Jun-89	12	c	2	42	2	9.3	10.1
13-Jun-89	12	c	2	55	2	9.3	10.1
13-Jun-89	12	c	2	91	2	9.3	10.1
13-Jun-89	12	c	2	33	2	9.4	10.2
13-Jun-89	12	c	2	57	2	9.7	10.4
13-Jun-89	12	c	2	56	2	10.3	11.0
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					MEAN	8.4	9.3
					SD	0.6	0.5
					N	99	99
13-Jun-89	13	A	2	64	2	7.3	8.4
13-Jun-89	13	A	2	23	2	7.3	8.4
13-Jun-89	13	A	2	86	1	7.6	8.6
13-Jun-89	13	A	2	71	2	7.6	8.6
13-Jun-89	13	A	2	1	1	7.6	8.6
13-Jun-89	13	A	2	77	2	7.6	8.6
13-Jun-89	13	A	2	46	2	7.8	8.8
13-Jun-89	13	A	2	39	2	7.8	8.8
13-Jun-89	13	A	2	94	2	7.8	8.8
13-Jun-89	13	A	2	43	2	7.8	8.8
13-Jun-89	13	A	2	25	2	7.8	8.8
13-Jun-89	13	A	2	87	2	7.9	8.9

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
13-Jun-89	13	A	2	45	2	7.9	8.9
13-Jun-89	13	A	2	40	1	8.1	9.0
13-Jun-89	13	A	2	66	2	8.2	9.1
13-Jun-89	13	A	2	91	2	8.2	9.1
13-Jun-89	13	A	2	13	2	8.2	9.1
13-Jun-89	13	A	2	47	2	8.2	9.1
13-Jun-89	13	A	2	69	2	8.2	9.1
13-Jun-89	13	A	2	2	2	8.2	9.1
13-Jun-89	13	A	2	93	2	8.2	9.1
13-Jun-89	13	A	2	14	2	8.2	9.1
13-Jun-89	13	A	2	76	2	8.4	9.3
13-Jun-89	13	A	2	95	2	8.4	9.3
13-Jun-89	13	A	2	21	2	8.4	9.3
13-Jun-89	13	A	2	33	2	8.4	9.3
13-Jun-89	13	A	2	52	2	8.4	9.3
13-Jun-89	13	A	2	31	2	8.4	9.3
13-Jun-89	13	A	2	62	2	8.4	9.3
13-Jun-89	13	A	2	92	2	8.4	9.3
13-Jun-89	13	A	2	16	2	8.4	9.3
13-Jun-89	13	A	2	34	2	8.4	9.3
13-Jun-89	13	A	2	51	2	8.5	9.4
13-Jun-89	13	A	2	30	2	8.5	9.4
13-Jun-89	13	A	2	78	2	8.5	9.4
13-Jun-89	13	A	2	96	2	8.5	9.4
13-Jun-89	13	A	2	17	2	8.5	9.4
13-Jun-89	13	A	2	37	2	8.5	9.4
13-Jun-89	13	A	2	72	1	8.5	9.4
13-Jun-89	13	A	2	27	2	8.5	9.4
13-Jun-89	13	A	2	89	2	8.5	9.4
13-Jun-89	13	A	2	19	2	8.5	9.4
13-Jun-89	13	A	2	26	2	8.5	9.4
13-Jun-89	13	A	2	12	2	8.7	9.6
13-Jun-89	13	A	2	32	2	8.7	9.6
13-Jun-89	13	A	2	10	2	8.7	9.6
13-Jun-89	13	A	2	2%	2	8.7	9.6

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
13-Jun-89	13	A	2	18	2	8.7	9.6
13-Jun-89	13	A	2	68	2	8.7	9.6
13-Jun-89	13	A	2	15	2	8.7	9.6
13-Jun-89	13	A	2	57	2	8.7	9.6
13-Jun-89	13	A	2	7	2	8.7	9.6
13-Jun-89	13	A	2	67	2	8.8	9.7
13-Jun-89	13	A	2	41	2	8.8	9.7
13-Jun-89	13	A	2	36	2	8.8	9.7
13-Jun-89	13	A	2	44	2	8.8	9.7
13-Jun-89	13	A	2	38	2	8.8	9.7
13-Jun-89	13	A	2	3	2	8.8	9.7
13-Jun-89	13	A	2	82	2	8.8	9.7
13-Jun-89	13	A	2	59	2	8.8	9.7
13-Jun-89	13	A	2	81	2	8.8	9.7
13-Jun-89	13	A	2	98	2	8.8	9.7
13-Jun-89	13	A	2	6	2	8.8	9.7
13-Jun-89	13	A	2	100	2	8.8	9.7
13-Jun-89	13	A	2	11	2	8.8	9.7
13-Jun-89	13	A	2	54	1	9.0	9.8
13-Jun-89	13	A	2	80	2	9.0	9.8
13-Jun-89	13	A	2	79	2	9.0	9.8
13-Jun-89	13	A	2	84	2	9.0	9.8
13-Jun-89	13	A	2	55	2	9.0	9.8
13-Jun-89	13	A	2	70	2	9.0	9.8
13-Jun-89	13	A	2	24	2	9.0	9.8
13-Jun-89	13	A	2	9	2	9.0	9.8
13-Jun-89	13	A	2	99	2	9.0	9.8
13-Jun-89	13	A	2	75	2	9.1	9.9
13-Jun-89	13	A	2	73	2	9.1	9.9
13-Jun-89	13	A	2	60	2	9.1	9.9
13-Jun-89	13	A	2	20	2	9.1	9.9
13-Jun-89	13	A	2	49	2	9.1	9.9
13-Jun-89	13	A	2	42	2	9.3	10.1
13-Jun-89	13	A	2	74	2	9.3	10.1
13-Jun-89	13	A	2	83	2	9.4	10.2

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
13-Jun-89	13	A	2	35	2	9.4	10.2
13-Jun-89	13	A	2	22	2	9.4	10.2
13-Jun-89	13	A	2	8	2	9.4	10.2
13-Jun-89	13	A	2	53	2	9.4	10.2
13-Jun-89	13	A	2	61	2	9.6	10.3
13-Jun-89	13	A	2	90	2	9.6	10.3
13-Jun-89	13	A	2	97	2	9.6	10.3
13-Jun-89	13	A	2	58	2	9.7	10.4
13-Jun-89	13	A	2	65	2	9.7	10.4
13-Jun-89	13	A	2	50	2	9.7	10.4
13-Jun-89	13	A	2	5	2	9.9	10.6
13-Jun-89	13	A	2	88	2	9.9	10.6
13-Jun-89	13	A	2	63	2	10.0	10.7
13-Jun-89	13	A	2	56	2	10.0	10.7
13-Jun-89	13	A	2	85	2	10.2	10.9
13-Jun-89	13	A	2	48	2	10.5	11.1
13-Jun-89	13	A	2	29	2	10.6	11.2
						--------------	--------------
					MEAN	8.7	9.6
					SD	0.7	0.6
					N	99	99
13-Jun-89	13	A	1	4	2	12.6	13.0
						--------------	--------------
					MEAN	12.6	13.0
					SD		
					N	1	1
13-Jun-89	14	c	2	45	1	6.6	7.8
13-Jun-89	14	c	2	10	1	6.7	7.9
13-Jun-89	14	c	2	43	1	7.0	8.1
13-Jun-89	14	c	2	3	2	7.0	8.1
13-Jun-89	14	c	2	34	1	7.0	8.1
13-Jun-89	14	c	2	51	2	7.2	8.3
13-Jun-89	14	C	2	26	1	7.2	8.3

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
13-Jun-89	14	c	2	18	1	7.2	8.3
13-Jun-89	14	c	2	66	1	7.2	8.3
13-Jun-89	14	c	2	57	1	7.2	8.3
13-Jun-89	14	c	2	55	2	7.3	8.4
13-Jun-89	14	c	2	40	2	7.3	8.4
13-Jun-89	14	c	2	60	1	7.3	8.4
13-Jun-89	14	c	2	48	1	7.5	8.5
13-Jun-89	14	c	2	6	1	7.5	8.5
13-Jun-89	14	c	2	86	2	7.5	8.5
13-Jun-89	14	c	2	35	2	7.5	8.5
13-Jun-89	14	c	2	62	1	7.5	8.5
13-Jun-89	14	c	2	49	1	7.5	8.5
13-Jun-89	14	c	2	98	1	7.5	8.5
13-Jun-89	14	c	2	31	1	7.5	8.5
13-Jun-89	14	c	2	54	1	7.6	8.6
13-Jun-89	14	c	2	96	2	7.6	8.6
13-Jun-89	14	c	2	30	2	7.6	8.6
13-Jun-89	14	c	2	67	2	7.6	8.6
13-Jun-89	14	c	2	87	2	7.8	8.8
13-Jun-89	14	c	2	36	2	7.8	8.8
13-Jun-89	14	c	2	82	1	7.8	8.8
13-Jun-89	14	c	2	88	2	7.8	8.8
13-Jun-89	14	c	2	44	1	7.8	8.8
13-Jun-89	14	c	2	70	1	7.9	8.9
13-Jun-89	14	c	2	68	2	7.9	8.9
13-Jun-89	14	c	2	22	2	7.9	8.9
13-Jun-89	14	c	2	24	2	7.9	8.9
13-Jun-89	14	c	2	56	2	8.1	9.0
13-Jun-89	14	c	2	94	2	8.1	9.0
13-Jun-89	14	c	2	77	1	8.1	9.0
13-Jun-89	14	c	2	50	2	8.1	9.0
13-Jun-89	14	c	2	14	2	8.1	9.0
13-Jun-89	14	c	2	20	1	8.1	9.0
13-Jun-89	14	c	2	15	1	8.1	9.0
13-Jun-89	14	c	2	46	2	8.1	9.0

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
13-Jun-89	14	C	2	17	2	8.2	9.1
13-Jun-89	14	C	2	25	2	8.2	9.1
13-Jun-89	14	C	2	93	2	8.2	9.1
13-Jun-89	14	C	2	8	2	8.2	9.1
13-Jun-89	14	C	2	28	1	8.2	9.1
13-Jun-89	14	C	2	74	2	8.2	9.1
13-Jun-89	14	C	2	81	2	8.2	9.1
13-Jun-89	14	C	2	78	2	8.2	9.1
13-Jun-89	14	C	2	83	2	8.2	9.1
13-Jun-89	14	C	2	52	2	8.4	9.3
13-Jun-89	14	C	2	13	1	8.4	9.3
13-Jun-89	14	C	2	53	2	8.4	9.3
13-Jun-89	14	C	2	76	2	8.4	9.3
13-Jun-89	14	C	2	95	2	8.4	9.3
13-Jun-89	14	C	2	19	2	8.4	9.3
13-Jun-89	14	C	2	69	2	8.4	9.3
13-Jun-89	14	C	2	61	2	8.4	9.3
13-Jun-89	14	C	2	63	2	8.5	9.4
13-Jun-89	14	C	2	84	1	8.5	9.4
13-Jun-89	14	C	2	9	2	8.5	9.4
13-Jun-89	14	C	2	47	2	8.5	9.4
13-Jun-89	14	C	2	58	2	8.5	9.4
13-Jun-89	14	C	2	41	2	8.5	9.4
13-Jun-89	14	C	2	97	2	8.5	9.4
13-Jun-89	14	C	2	38	2	8.5	9.4
13-Jun-89	14	C	2	92	2	8.5	9.4
13-Jun-89	14	C	2	90	2	8.5	9.4
13-Jun-89	14	C	2	7	2	8.7	9.6
13-Jun-89	14	C	2	59	2	8.7	9.6
13-Jun-89	14	C	2	65	2	8.7	9.6
13-Jun-89	14	C	2	85	2	8.7	9.6
13-Jun-89	14	C	2	80	2	8.7	9.6
13-Jun-89	14	C	2	32	2	8.7	9.6
13-Jun-89	14	C	2	42	2	8.7	9.6
13-Jun-89	14	C	2	23	2	8.7	9.6

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
13-Jun-89	14	c	2	4	2	8.7	9.6
13-Jun-89	14	c	2	75	2	8.8	9.7
13-Jun-89	14	c	2	21	2	8.8	9.7
13-Jun-89	14	C	2	5	2	8.8	9.7
13-Jun-89	14	c	2	11	2	8.8	9.7
13-Jun-89	14	c	2	39	2	8.8	9.7
13-Jun-89	14	c	2	64	1	8.8	9.7
13-Jun-89	14	c	2	100	1	8.8	9.7
13-Jun-89	14	c	2	72	2	9.0	9.8
13-Jun-89	14	c	2	33	2	9.0	9.8
13-Jun-89	14	c	2	99	2	9.0	9.8
13-Jun-89	14	c	2	12	2	9.1	9.9
13-Jun-89	14	c	2	29	2	9.1	9.9
13-Jun-89	14	c	2	91	2	9.1	9.9
13-Jun-89	14	c	2	79	2	9.1	9.9
13-Jun-89	14	c	2	16	2	9.3	10.1
13-Jun-89	14	c	2	37	2	9.3	10.1
13-Jun-89	14	c	2	1	2	9.4	10.2
13-Jun-89	14	c	2	89	2	9.4	10.2
13-Jun-89	14	c	2	27	2	9.4	10.2
13-Jun-89	14	c	2	71	2	9.6	10.3
13-Jun-89	14	c	2	73	2	9.6	10.3
13-Jun-89	14	c	2	2	2	9.7	10.4
						--------------	--------------
					MEAN	8.2	9.2
					SD	0.7	0.6
					N	100	100
13-Jun-89	17	E	2	24	1	6.9	8.0
13-Jun-89	17	E	2	37	2	7.5	8.5
13-Jun-89	17	E	2	61	2	7.5	8.5
13-Jun-89	17	E	2	63	2	7.5	8.5
13-Jun-89	17	E	2	21	2	7.5	8.5
13-Jun-89	17	E	2	41	1	7.5	8.5
13-Jun-89	17	E	2	45	2	7.6	8.6

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
13-Jun-89	17	E	2	32	2	7.8	8.8
13-Jun-89	17	E	2	59	2	7.8	8.8
13-Jun-89	17	E	2	36	2	7.9	8.9
13-Jun-89	17	E	2	11	2	7.9	8.9
13-Jun-89	17	E	2	12	2	7.9	8.9
13-Jun-89	17	E	2	62	2	7.9	8.9
13-Jun-89	17	E	2	68	2	7.9	8.9
13-Jun-89	17	E	2	44	2	8.1	9.0
13-Jun-89	17	E	2	13	2	8.1	9.0
13-Jun-89	17	E	2	30	2	8.1	9.0
13-Jun-89	17	E	2	18	2	8.1	9.0
13-Jun-89	17	E	2	15	1	8.1	9.0
13-Jun-89	17	E	2	27	2	8.1	9.0
13-Jun-89	17	E	2	23	2	8.2	9.1
13-Jun-89	17	E	2	33	2	8.2	9.1
13-Jun-89	17	E	2	66	2	8.2	9.1
13-Jun-89	17	E	2	56	2	8.2	9.1
13-Jun-89	17	E	2	55	2	8.2	9.1
13-Jun-89	17	E	2	58	1	8.2	9.1
13-Jun-89	17	E	2	2	2	8.2	9.1
13-Jun-89	17	E	2	1	2	8.4	9.3
13-Jun-89	17	E	2	20	2	8.4	9.3
13-Jun-89	17	E	2	46	2	8.4	9.3
13-Jun-89	17	E	2	31	2	8.4	9.3
13-Jun-89	17	E	2	50	1	8.4	9.3
13-Jun-89	17	E	2	10	2	8.4	9.3
13-Jun-89	17	E	2	47	2	8.4	9.3
13-Jun-89	17	E	2	67	2	8.4	9.3
13-Jun-89	17	E	2	3	1	8.5	9.4
13-Jun-89	17	E	2	9	1	8.5	9.4
13-Jun-89	17	E	2	19	2	8.5	9.4
13-Jun-89	17	E	2	34	2	8.5	9.4
13-Jun-89	17	E	2	14	1	8.5	9.4
13-Jun-89	17	E	2	60	2	8.5	9.4
13-Jun-89	17	E	2	17	2	8.5	9.4

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
13-Jun-89	17	E	2	39	2	8.5	9.4
13-Jun-89	17	E	2	49	2	8.7	9.6
13-Jun-89	17	E	2	6	2	8.7	9.6
13-Jun-89	17	E	2	26	2	8.7	9.6
13-Jun-89	17	E	2	38	2	8.7	9.6
13-Jun-89	17	E	2	48	1	8.8	9.7
13-Jun-89	17	E	2	4	2	8.8	9.7
13-Jun-89	17	E	2	16	2	8.8	9.7
13-Jun-89	17	E	2	42	2	8.8	9.7
13-Jun-89	17	E	2	65	2	8.8	9.7
13-Jun-89	17	E	2	53	2	8.8	9.7
13-Jun-89	17	E	2	52	2	8.8	9.7
13-Jun-89	17	E	2	22	2	8.8	9.7
13-Jun-89	17	E	2	57	2	8.8	9.7
13-Jun-89	17	E	2	5	2	9.0	9.8
13-Jun-89	17	E	2	64	2	9.0	9.8
13-Jun-89	17	E	2	7	2	9.0	9.8
13-Jun-89	17	E	2	35	2	9.1	9.9
13-Jun-89	17	E	2	43	2	9.1	9.9
13-Jun-89	17	E	2	51	2	9.1	9.9
13-Jun-89	17	E	2	8	2	9.4	10.2
13-Jun-89	17	E	2	28	2	9.6	10.3
13-Jun-89	17	E	2	29	2	9.6	10.3
13-Jun-89	17	E	2	40	2	10.2	10.9
13-Jun-89	17	E	2	54	2	10.5	11.1
					MEAN	8.4	9.3
					SD	0.6	0.5
					N	67	67
			2 GRAND MEAN			8.4	9.3
					SD	0.6	0.5
					N	465	465
			1 GRAND MEAN			12.6	13.0

Appendix E. Lengths ofherring larvae inport Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
					SD		
					N	1	1
14-Jun-89	15	F	-				
						--------------	--------------
					MEAN		
					SD		
					N		
14-Jun-89	16	J	2	13	2	7.6	8.6
14-Jun-89	16	J	2	12	2	7.8	8.8
14-Jun-89	16	J	2	10	2	7.9	8.9
14-Jun-89	16	J	2	4	2	8.2	9.1
14-Jun-89	16	J	2	1	2	8.4	9.3
14-Jun-89	16	J	2	14	2	8.4	9.3
14-Jun-89	16	J	2	8	2	8.5	9.4
14-Jun-89	16	J	2	5	2	8.5	9.4
14-Jun-89	16	J	2	15	2	8.5	9.4
14-Jun-89	16	J	2	2	2	8.7	9.6
14-Jun-89	16	J	2	7	2	8.8	9.7
14-Jun-89	16	J	2	6	2	8.8	9.7
14-Jun-89	16	J	2	3	2	9.1	9.9
14-Jun-89	16	J	2	9	2	9.3	10.1
						--------------	--------------
					MEAN	8.5	9.4
					SD	0.5	0.4
					N	14	14
14-Jun-89	16	J	1	11	2	11.1	11.7
						--------------	--------------
					MEAN	11.1	11.7
					SD		
					N	1	1
14-Jun-89	18	N	2	90	2	6.7	7.9

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	18	N	2	22	2	7.0	8.1
14-Jun-89	18	N	2	57	2	7.2	8.3
14-Jun-89	18	N	2	87	2	7.2	8.3
14-Jun-89	18	N	2	83	2	7.3	8.4
14-Jun-89	18	N	2	25	1	7.3	8.4
14-Jun-89	18	N	2	46	2	7.5	8.5
14-Jun-89	18	N	2	94	2	7.5	8.5
14-Jun-89	18	N	2	14	2	7.5	8.5
14-Jun-89	18	N	2	37	2	7.6	8.6
14-Jun-89	18	N	2	64	2	7.6	8.6
14-Jun-89	18	N	2	40	2	7.6	8.6
14-Jun-89	18	N	2	98	2	7.6	8.6
14-Jun-89	18	N	2	52	2	7.6	8.6
14-Jun-89	18	N	2	29	2	7.8	8.8
14-Jun-89	18	N	2	58	2	7.8	8.8
14-Jun-89	18	N	2	41	2	7.8	8.8
14-Jun-89	18	N	2	34	2	7.9	8.9
14-Jun-89	18	N	2	89	2	7.9	8.9
14-Jun-89	18	N	2	8	2	7.9	8.9
14-Jun-89	18	N	2	93	2	7.9	8.9
14-Jun-89	18	N	2	99	2	8.1	9.0
14-Jun-89	18	N	2	50	2	8.1	9.0
14-Jun-89	18	N	2	36	1	8.1	9.0
14-Jun-89	18	N	2	60	2	8.2	9.1
14-Jun-89	18	N	2	30	2	8.2	9.1
14-Jun-89	18	N	2	38	2	8.2	9.1
14-Jun-89	18	N	2	16	1	8.2	9.1
14-Jun-89	18	N	2	62	2	8.2	9.1
14-Jun-89	18	N	2	67	2	8.2	9.1
14-Jun-89	18	N	2	20	2	8.2	9.1
14-Jun-89	18	N	2	1	2	8.2	9.1
14-Jun-89	18	N	2	55	2	8.2	9.1
14-Jun-89	18	N	2	7	2	8.4	9.3
14-Jun-89	18	N	2	19	2	8.4	9.3
14-Jun-89	18	N	2	75	2	8.4	9.3

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	18	N	2	17	2	8.4	9.3
14-Jun-89	18	N	2	95	2	8.4	9.3
14-Jun-89	18	N	2	74	2	8.4	9.3
14-Jun-89	18	N	2	3	2	8.4	9.3
14-Jun-89	18	N	2	78	2	8.5	9.4
14-Jun-89	18	N	2	47	2	8.5	9.4
14-Jun-89	18	N	2	70	2	8.5	9.4
14-Jun-89	18	N	2	73	2	8.5	9.4
14-Jun-89	18	N	2	84	2	8.5	9.4
14-Jun-89	18	N	2	39	2	8.5	9.4
14-Jun-89	18	N	2	4	2	8.5	9.4
14-Jun-89	18	N	2	91	2	8.5	9.4
14-Jun-89	18	N	2	59	2	8.5	9.4
14-Jun-89	18	N	2	72	2	. 8.5	9.4
14-Jun-89	18	N	2	48	2	8.7	9.6
14-Jun-89	18	N	2	56	2	8.7	9.6
14-Jun-89	18	N	2	100	2	8.7	9.6
14-Jun-89	18	N	2	71	2	8.7	9.6
14-Jun-89	18	N	2	45	2	8.7	9.6
14-Jun-89	18	N	2	2	2	8.7	9.6
14-Jun-89	18	N	2	35	2	8.7	9.6
14-Jun-89	18	N	2	5	2	8.7	9.6
14-Jun-89	18	N	2	28	2	8.7	9.6
14-Jun-89	18	N	2	79	2	8.8	9.7
14-Jun-89	18	N	2	24	2	8.8	9.7
14-Jun-89	18	N	2	10	2	8.8	9.7
14-Jun-89	18	N	2	88	2	8.8	9.7
14-Jun-89	18	N	2	32	2	8.8	9.7
14-Jun-89	18	N	2	23	2	8.8	9.7
14-Jun-89	18	N	2	51	2	9.0	9.8
14-Jun-89	18	N	2	65	2	9.0	9.8
14-Jun-89	18	N	2	43	2	9.0	9.8
14-Jun-89	18	N	2	44	2	9.0	9.8
14-Jun-89	18	N	2	92	2	9.1	9.9
14-Jun-89	18	N	2	18	2	9.1	9.9

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	18	N	2	82	2	9.1	9.9
14-Jun-89	18	N	2	85	2	9.1	9.9
14-Jun-89	18	N	2	80	2	9.1	9.9
14-Jun-89	18	N	2	86	2	9.3	10.1
14-Jun-89	18	N	2	69	2	9.3	10.1
14-Jun-89	18	N	2	61	2	9.3	10.1
14-Jun-89	18	N	2	76	2	9.3	10.1
14-Jun-89	18	N	2	96	2	9.3	10.1
14-Jun-89	18	N	2	33	2	9.4	10.2
14-Jun-89	18	N	2	54	2	9.4	10.2
14-Jun-89	18	N	2	27	2	9.4	10.2
14-Jun-89	18	N	2	26	2	9.4	10.2
14-Jun-89	18	N	2	42	2	9.4	10.2
14-Jun-89	18	N	2	6	2	9.4	10.2
14-Jun-89	18	N	2	15	2	9.4	10.2
14-Jun-89	18	N	2	21	2	9.6	10.3
14-Jun-89	18	N	2	77	2	9.6	10.3
14-Jun-89	18	N	2	63	2	9.6	10.3
14-Jun-89	18	N	2	66	2	9.6	10.3
14-Jun-89	18	N	2	11	2	9.6	10.3
14-Jun-89	18	N	2	9	2	9.6	10.3
14-Jun-89	18	N	2	53	2	9.6	10.3
14-Jun-89	18	N	2	81	2	9.7	10.4
14-Jun-89	18	N	2	49	2	9.7	10.4
14-Jun-89	18	N	2	68	2	9.7	10.4
14-Jun-89	18	N	2	13	2	9.9	10.6
14-Jun-89	18	N	2	31	2	9.9	10.6
14-Jun-89	18	N	2	97	2	10.3	11.0
14-Jun-89	18	N	2	12	2	10.6	11.2
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					MEAN	8.6	9.5
					SD	0.8	0.7
					N	100	100
14-Jun-89	19	M	2	74	1	6.6	7.8

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	19	M	2	29	1	6.6	7.8
14-Jun-89	19	M	2	81	2	6.9	8.0
14-Jun-89	19	M	2	3	1	6.9	8.0
14-Jun-89	19	M	2	16	2	6.9	8.0
14-Jun-89	19	M	2	37	2	6.9	8.0
14-Jun-89	19	M	2	84	2	7.0	8.1
14-Jun-89	19	M	2	49	2	7.0	8.1
14-Jun-89	19	M	2	9	1	7.2	8.3
14-Jun-89	19	M	2	70	2	7.3	8.4
14-Jun-89	19	M	2	4	1	7.3	8.4
14-Jun-89	19	M	2	12	2	7.5	8.5
14-Jun-89	19	M	2	10	2	7.5	8.5
14-Jun-89	19	M	2	42	2	7.5	8.5
14-Jun-89	19	M	2	15	2	7.5	8.5
14-Jun-89	19	M	2	85	2	7.5	8.5
14-Jun-89	19	M	2	17	2	7.5	8.5
14-Jun-89	19	M	2	40	2	7.6	8.6
14-Jun-89	19	M	2	92	2	7.6	8.6
14-Jun-89	19	M	2	32	1	7.6	8.6
14-Jun-89	19	M	2	87	2	7.6	8.6
14-Jun-89	19	M	2	55	2	7.6	8.6
14-Jun-89	19	M	2	93	2	7.8	8.8
14-Jun-89	19	M	2	38	1	7.8	8.8
14-Jun-89	19	M	2	65	2	7.8	8.8
14-Jun-89	19	M	2	18	2	7.8	8.8
14-Jun-89	19	M	2	53	2	7.8	8.8
14-Jun-89	19	M	2	79	2	7.8	8.8
14-Jun-89	19	M	2	50	2	7.8	8.8
14-Jun-89	19	M	2	73	2	7.9	8.9
14-Jun-89	19	M	2	100	2	7.9	8.9
14-Jun-89	19	M	2	20	2	7.9	8.9
14-Jun-89	19	M	2	68	2	7.9	8.9
14-Jun-89	19	M	2	24	2	7.9	8.9
14-Jun-89	19	M	2	72	2	8.1	9.0
14-Jun-89	19	M	2	62	2	8.1	9.0

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	19	M	2	33	2	8.1	9.0
14-Jun-89	19	M	2	48	1	8.1	9.0
14-Jun-89	19	M	2	34	2	8.1	9.0
14-Jun-89	19	M	2	95	1	8.1	9.0
14-Jun-89	19	M	2	76	2	8.1	9.0
14-Jun-89	19	M	2	21	1	8.1	9.0
14-Jun-89	19	M	2	97	2	8.2	9.1
14-Jun-89	19	M	2	14	1	8.2	9.1
14-Jun-89	19	M	2	26	2	8.2	9.1
14-Jun-89	19	M	2	57	2	8.2	9.1
14-Jun-89	19	M	2	69	2	8.2	9.1
14-Jun-89	19	M	2	11	2	8.4	9.3
14-Jun-89	19	M	2	66	2	8.4	9.3
14-Jun-89	19	M	2	22	2	8.4	9.3
14-Jun-89	19	M	2	28	2	8.4	9.3
14-Jun-89	19	M	2	39	1	8.5	9.4
14-Jun-89	19	M	2	77	2	8.5	9.4
14-Jun-89	19	M	2	90	2	8.5	9.4
14-Jun-89	19	M	2	44	2	8.5	9.4
14-Jun-89	19	M	2	80	2	8.5	9.4
14-Jun-89	19	M	2	5	1	8.5	9.4
14-Jun-89	19	M	2	63	2	8.5	9.4
14-Jun-89	19	M	2	88	2	8.7	9.6
14-Jun-89	19	M	2	30	2	8.7	9.6
14-Jun-89	19	M	2	86	2	8.7	9.6
14-Jun-89	19	M	2	1	2	8.7	9.6
14-Jun-89	19	M	2	45	2	8.7	9.6
14-Jun-89	19	M	2	94	2	8.8	9.7
14-Jun-89	19	M	2	13	2	8.8	9.7
14-Jun-89	19	M	2	54	2	8.8	9.7
14-Jun-89	19	M	2	67	2	9.0	9.8
14-Jun-89	19	M	2	25	2	9.0	9.8
14-Jun-89	19	M	2	8	2	9.0	9.8
14-Jun-89	19	M	2	52	2	9.0	9.8
14-Jun-89	19	M	2	58	2	9.0	9.8

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	19	M	2	82	2	9.1	9.9
14-Jun-89	19	M	2	99	2	9.1	9.9
14-Jun-89	19	M	2	61	2	9.1	9.9
14-Jun-89	19	M	2	47	2	9.1	9.9
14-Jun-89	19	M	2	46	2	9.1	9.9
14-Jun-89	19	M	2	51	2	9.3	10.1
14-Jun-89	19	M	2	6	2	9.3	10.1
14-Jun-89	19	M	2	59	2	9.3	10.1
14-Jun-89	19	M	2	36	2	9.3	10.1
14-Jun-89	19	M	2	31	2	9.4	10.2
14-Jun-89	19	M	2	27	2	9.6	10.3
14-Jun-89	19	M	2	98	2	9.6	10.3
14-Jun-89	19	M	2	2	2	9.6	10.3
14-Jun-89	19	M	2	91	2	9.6	10.3
14-Jun-89	19	M	2	89	2	9.7	10.4
14-Jun-89	19	M	2	78	2	9.7	10.4
14-Jun-89	19	M	2	71	2	9.7	10.4
14-Jun-89	19	M	2	83	2	9.7	10.4
14-Jun-89	19	M	2	41	2	9.7	10.4
14-Jun-89	19	M	2	23	2	9.9	10.6
14-Jun-89	19	M	2	7	2	10.0	10.7
14-Jun-89	19	M	2	64	2	10.0	10.7
14-Jun-89	19	M	2	96	2	10.3	11.0
14-Jun-89	19	M	2	19	2	10.3	11.0
14-Jun-89	19	M	2	60	2	10.6	11.2
14-Jun-89	19	M	2	43	2	10.9	11.5
						--------------	--------------
					MEAN	8.4	9.3
					SD	0.9	0.8
					N	97	97
14-Jun-89	19	M	1	35	2	11.1	11.7
14-Jun-89	19	M	1	75	2	11.1	11.7
14-Jun-89	19	M	1	56	2	12.1	12.6
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Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
					MEAN	11.4	12.0
					SD	0.6	0.5
					N	3	3
14-Jun-89	20	L	2	18	2	7.8	8.8
14-Jun-89	20	L	2	2	2	7.8	8.8
14-Jun-89	20	L	2	19	2	7.8	8.8
14-Jun-89	20	L	2	8	2	8.1	9.0
14-Jun-89	20	L	2	13	2	8.1	9.0
14-Jun-89	20	L	2	5	2	8.2	9.1
14-Jun-89	20	L	2	16	2	8.4	9.3
14-Jun-89	20	L	2	4	2	8.4	9.3
14-Jun-89	20	L	2	11	2	8.5	9.4
14-Jun-89	20	L	2	12	2	8.5	9.4
14-Jun-89	20	L	2	6	2	8.5	9.4
14-Jun-89	20	L	2	9	2	8.5	9.4
14-Jun-89	20	L	2	14	2	8.7	9.6
14-Jun-89	20	L	2	10	2	8.8	9.7
14-Jun-89	20	L	2	7	2	8.8	9.7
14-Jun-89	20	L	2	3	2	8.8	9.7
14-Jun-89	20	L	2	15	2	9.0	9.8
14-Jun-89	20	L	2	1	2	9.7	10.4
						--------------	--------------
					MEAN	8.5	9.4
					SD	0.5	0.4
					N	18	18
14-Jun-89	21	K	2	27	2	6.6	7.8
14-Jun-89	21	K	2	24	2	7.2	8.3
14-Jun-89	21	K	2	19	2	7.2	8.3
14-Jun-89	21	K	2	25	2	7.5	8.5
14-Jun-89	21	K	2	23	2	7.8	8.8
14-Jun-89	21	K	2	16	2	7.8	8.8
14-Jun-89	21	K	2	20	2	7.8	8.8

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	21	K	2	22	2	7.9	8.9
14-Jun-89	21	K	2	12	1	7.9	8.9
14-Jun-89	21	K	2	11	2	8.1	9.0
14-Jun-89	21	K	2	15	2	8.2	9.1
14-Jun-89	21	K	2	18	2	8.2	9.1
14-Jun-89	21	K	2	26	2	8.2	9.1
14-Jun-89	21	K	2	4	2	8.4	9.3
14-Jun-89	21	K	2	14	2	8.4	9.3
14-Jun-89	21	K	2	2	2	8.4	9.3
14-Jun-89	21	K	2	10	2	8.4	9.3
14-Jun-89	21	K	2	9	2	8.5	9.4
14-Jun-89	21	K	2	21	2	8.5	9.4
14-Jun-89	21	K	2	8	2	8.7	9.6
14-Jun-89	21	K	2	6	2	8.8	9.7
14-Jun-89	21	K	2	7	2	9.0	9.8
14-Jun-89	21	K	2	17	2	9.0	9.8
14-Jun-89	21	K	2	3	2	9.4	10.2
					MEAN	8.2	9.1
					SD	0.6	0.5
					N	24	24
14-Jun-89	21	K	1	5	2	11.1	11.7
14-Jun-89	21	K	1	1	2	12.7	13.1
					MEAN	11.9	12.4
					SD	1.1	1.0
					N	2	2
14-Jun-89	22	A	2	57	1	7.3	8.4
14-Jun-89	22	A	2	44	1	7.3	8.4
14-Jun-89	22	A	2	60	1	7.5	8.5
14-Jun-89	22	A	2	94	1	7.6	8.6
14-Jun-89	22	A	2	21	2	7.8	8.8
14-Jun-89	22	A	2	2	2	7.9	8.9

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	22	A	2	38	1	7.9	8.9
14-Jun-89	22	A	2	99	2	8.1	9.0
14-Jun-89	22	A	2	79	2	8.1	9.0
14-Jun-89	22	A	2	69	1	8.1	9.0
14-Jun-89	22	A	2	100	2	8.2	9.1
14-Jun-89	22	A	2	65	2	8.2	9.1
14-Jun-89	22	A	2	17	1	8.2	9.1
14-Jun-89	22	A	2	78	2	8.2	9.1
14-Jun-89	22	A	2	43	1	8.2	9.1
14-Jun-89	22	A	2	72	2	8.2	9.1
14-Jun-89	22	A	2	47	2	8.4	9.3
14-Jun-89	22	A	2	27	2	8.4	9.3
14-Jun-89	22	A	2	90	2	8.4	9.3
14-Jun-89	22	A	2	6	1	8.4	9.3
14-Jun-89	22	A	2	93	1	8.4	9.3
14-Jun-89	22	A	2	11	1	8.4	9.3
14-Jun-89	22	A	2	62	2	8.4	9.3
14-Jun-89	22	A	2	96	1	8.4	9.3
14-Jun-89	22	A	2	46	2	8.5	9.4
14-Jun-89	22	A	2	23	2	8.5	9.4
14-Jun-89	22	A	2	8	2	8.5	9.4
14-Jun-89	22	A	2	52	2	8.5	9.4
14-Jun-89	22	A	2	59	1	8.7	9.6
14-Jun-89	22	A	2	28	1	8.7	9.6
14-Jun-89	22	A	2	80	2	8.7	9.6
14-Jun-89	22	A	2	89	2	8.7	9.6
14-Jun-89	22	A	2	24	2	8.7	9.6
14-Jun-89	22	A	2	50	2	8.7	9.6
14-Jun-89	22	A	2	29	2	8.7	9.6
14-Jun-89	22	A	2	25	2	8.8	9.7
14-Jun-89	22	A	2	64	2	8.8	9.7
14-Jun-89	22	A	2	14	2	8.8	9.7
14-Jun-89	22	A	2	7	2	8.8	9.7
14-Jun-89	22	A	2	53	2	8.8	9.7
14-Jun-89	22	A	2	10	2	8.8	9.7

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	22	A	2	81	2	8.8	9.7
14-Jun-89	22	A	2	77	1	8.8	9.7
14-Jun-89	22	A	2	67	2	8.8	9.7
14-Jun-89	22	A	2	48	2	8.8	9.7
14-Jun-89	22	A	2	82	2	8.8	9.7
14-Jun-89	22	A	2	61	2	9.0	9.8
14-Jun-89	22	A	2	70	2	9.0	9.8
14-Jun-89	22	A	2	19	2	9.0	9.8
14-Jun-89	22	A	2	71	2	9.0	9.8
14-Jun-89	22	A	2	34	2	9.0	9.8
14-Jun-89	22	A	2	76	2	9.0	9.8
14-Jun-89	22	A	2	32	2	9.0	9.8
14-Jun-89	22	A	2	98	2	9.0	9.8
14-Jun-89	22	A	2	33	2	9.0	9.8
14-Jun-89	22	A	2	68	2	9.0	9.8
14-Jun-89	22	A	2	91	2	9.1	9.9
14-Jun-89	22	A	2	75	2	9.1	9.9
14-Jun-89	22	A	2	58	2	9.1	9.9
14-Jun-89	22	A	2	55	2	9.1	9.9
14-Jun-89	22	A	2	54	2	9.1	9.9
14-Jun-89	22	A	2	87	2	9.1	9.9
14-Jun-89	22	A	2	84	2	9.1	9.9
14-Jun-89	22	A	2	95	2	9.1	9.9
14-Jun-89	22	A	2	20	2	9.1	9.9
14-Jun-89	22	A	2	40	2	9.1	9.9
14-Jun-89	22	A	2	39	2	9.3	10.1
14-Jun-89	22	A	2	92	2	9.3	10.1
14-Jun-89	22	A	2	31	2	9.3	10.1
14-Jun-89	22	A	2	86	2	9.3	10.1
14-Jun-89	22	A	2	88	2	9.3	10.1
14-Jun-89	22	A	2	26	2	9.3	10.1
14-Jun-89	22	A	2	9	2	9.3	10.1
14-Jun-89	22	A	2	3	2	9.3	10.1
14-Jun-89	22	A	2	66	2	9.3	10.1
14-Jun-89	22	A	2	42	2	9.3	10.1

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	22	A	2	36	2	9.4	10.2
14-Jun-89	22	A	2	74	2	9.4	10.2
14-Jun-89	22	A	2	35	2	9.4	10.2
14-Jun-89	22	A	2	85	2	9.4	10.2
14-Jun-89	22	A	2	30	2	9.4	10.2
14-Jun-89	22	A	2	5	2	9.4	10.2
14-Jun-89	22	A	2	13	2	9.4	10.2
14-Jun-89	22	A	2	12	2	9.4	10.2
14-Jun-89	22	A	2	15	2	9.6	10.3
14-Jun-89	22	A	2	56	2	9.6	10.3
14-Jun-89	22	A	2	45	2	9.6	10.3
14-Jun-89	22	A	2	49	2	9.6	10.3
14-Jun-89	22	A	2	1	2	9.6	10.3
14-Jun-89	22	A	2	97	2	9.6	10.3
14-Jun-89	22	A	2	51	2	9.7	10.4
14-Jun-89	22	A	2	63	2	9.7	10.4
14-Jun-89	22	A	2	4	2	9.7	10.4
14-Jun-89	22	A	2	41	2	9.7	10.4
14-Jun-89	22	A	2	18	2	9.9	10.6
14-Jun-89	22	A	2	37	2	10.2	10.9
14-Jun-89	22	A	2	22	2	10.2	10.9
14-Jun-89	22	A	2	16	2	10.2	10.9
14-Jun-89	22	A	2	73	1	10.3	11.0
14-Jun-89	22	A	2	83	2	10.5	11.1
						--------------	--------------
					MEAN	8.9	9.8
					SD	0.6	0.6
					N	100	100
14-Jun-89	23	B	2	88	2	6.4	7.6
14-Jun-89	23	B	2	87	2	6.7	7.9
14-Jun-89	23	B	2	23	1	6.9	8.0
14-Jun-89	23	B	2	39	1	6.9	8.0
14-Jun-89	23	B	2	51	2	7.2	8.3
14-Jun-89	23	B	2	57	1	7.2	8.3

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	2 3	B	2	83	1	7.3	8.4
14-Jun-89	2 3	B	2	56	2	7.3	8.4
14-Jun-89	2 3	B	2	71	2	7.5	8.5
14-Jun-89	2 3	B	2	98	1	7.5	8.5
14-Jun-89	2 3	B	2	45	1	7.5	8.5
14-Jun-89	2 3	B	2	36	1	7.5	8.5
14-Jun-89	2 3	B	2	3	1	7.5	8.5
14-Jun-89	2 3	B	2	92	1	7.5	8.5
14-Jun-89	2 3	B	2	40	2	7.5	8.5
14-Jun-89	2 3	B	2	6	2	7.6	8.6
14-Jun-89	2 3	B	2	84	1	7.6	8.6
14-Jun-89	2 3	B	2	15	2	7.6	8.6
14-Jun-89	2 3	B	2	30	1	7.6	8.6
14-Jun-89	2 3	B	2	82	1	7.6	8.6
14-Jun-89	2 3	B	2	100	1	7.8	8.8
14-Jun-89	2 3	B	2	79	2	7.8	8.8
14-Jun-89	2 3	B	2	89	2	7.8	8.8
14-Jun-89	2 3	B	2	81	2	7.8	8.8
14-Jun-89	2 3	B	2	69	1	7.9	8.9
14-Jun-89	2 3	B	2	68	2	7.9	8.9
14-Jun-89	2 3	B	2	99	2	7.9	8.9
14-Jun-89	2 3	B	2	54	2	7.9	8.9
14-Jun-89	2 3	B	2	18	2	8.1	9.0
14-Jun-89	2 3	B	2	32	1	8.1	9.0
14-Jun-89	2 3	B	2	4	2	8.1	9.0
14-Jun-89	2 3	B	2	55	1	8.1	9.0
14-Jun-89	2 3	B	2	43	2	8.1	9.0
14-Jun-89	2 3	B	2	49	2	8.2	9.1
14-Jun-89	2 3	B	2	28	2	8.2	9.1
14-Jun-89	2 3	B	2	62	1	8.2	9.1
14-Jun-89	2 3	B	2	96	2	8.2	9.1
14-Jun-89	2 3	B	2	47	1	8.2	9.1
14-Jun-89	2 3	B	2	86	1	8.2	9.1
14-Jun-89	2 3	B	2	42	2	8.4	9.3
14-Jun-89	2 3	B	2	91	2	8.4	9.3

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	23	B	2	50	2	8.4	9.3
14-Jun-89	23	B	2	33	1	8.4	9.3
14-Jun-89	23	B	2	73	1	8.4	9.3
14-Jun-89	23	B	2	65	2	8.4	9.3
14-Jun-89	23	B	2	12	2	8.5	9.4
14-Jun-89	23	B	2	27	2	8.5	9.4
14-Jun-89	23	B	2	46	2	8.5	9.4
14-Jun-89	2 3	B	2	61	2	8.5	9.4
14-Jun-89	23	B	2	22	2	8.5	9.4
14-Jun-89	23	B	2	64	2	8.5	9.4
14-Jun-89	23	B	2	63	2	8.7	9.6
14-Jun-89	23	B	2	59	2	8.7	9.6
14-Jun-89	23	B	2	10	2	8.7	9.6
14-Jun-89	23	B	2	16	2	8.7	9.6
14-Jun-89	23	B	2	77	2	8.7	9.6
14-Jun-89	23	B	2	78	2	8.8	9.7
14-Jun-89	23	B	2	21	2	8.8	9.7
14-Jun-89	23	B	2	52	2	8.8	9.7
14-Jun-89	23	B	2	5	2	8.8	9.7
14-Jun-89	23	B	2	11	2	8.8	9.7
14-Jun-89	23	B	2	80	2	8.8	9.7
14-Jun-89	2 3	B	2	60	2	8.8	9.7
14-Jun-89	23	B	2	17	1	8.8	9.7
14-Jun-89	23	B	2	75	2	8.8	9.7
14-Jun-89	23	B	2	58	2	9.0	9.8
14-Jun-89	23	B	2	90	2	9.0	9.8
14-Jun-89	23	B	2	37	2	9.0	9.8
14-Jun-89	23	B	2	94	2	9.0	9.8
14-Jun-89	23	B	2	85	2	9.0	9.8
14-Jun-89	23	B	2	1	2	9.1	9.9
14-Jun-89	23	B	2	26	2	9.1	9.9
14-Jun-89	23	B	2	13	1	9.1	9.9
14-Jun-89	23	B	2	29	2	9.3	10.1
14-Jun-89	23	B	2	41	2	9.3	10.1
14-Jun-89	23	B	2	9	2	9.3	10.1

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	2 3	B	2	95	1	9.3	10.1
14-Jun-89	23	B	2	66	2	9.3	10.1
14-Jun-89	23	B	2	2	2	9.3	10.1
14-Jun-89	23	B	2	8	2	9.4	10.2
14-Jun-89	23	B	2	24	2	9.4	10.2
14-Jun-89	23	B	2	72	2	9.4	10.2
14-Jun-89	23	B	2	44	2	9.4	10.2
14-Jun-89	23	B	2	31	2	9.6	10.3
14-Jun-89	23	B	2	97	2	9.6	10.3
14-Jun-89	23	B	2	7	2	9.6	10.3
14-Jun-89	23	B	2	20	2	9.7	10.4
14-Jun-89	23	B	2	14	1	9.7	10.4
14-Jun-89	23	B	2	70	2	9.7	10.4
14-Jun-89	23	B	2	76	1	9.9	10.6
14-Jun-89	23	B	2	74	1	10.5	11.1
14-Jun-89	23	B	2	35	1	10.5	11.1
14-Jun-89	23	B	2	25	2	10.5	11.1
14-Jun-89	23	B	2	48	2	10.6	11.2
14-Jun-89	23	B	2	93	2	10.6	11.2
14-Jun-89	23	B	2	38	2	10.8	11.4
14-Jun-89	23	B	2	67	2	10.8	11.4
14-Jun-89	23	B	2	34	1	10.8	11.4
14-Jun-89	23	B	2	53	2	10.9	11.5
						--------------	--------------
					MEAN	8.6	9.5
					SD	1.0	0.9
					N	99	99
14-Jun-89	23	B	1	19	2	11.5	12.0
						--------------	--------------
					MEAN	11.5	12.0
					SD		
					N	1	1
14-Jun-89	24	C	2	62	2	7.3	8.4

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	24	C	2	20	1	7.5	8.5
14-Jun-89	24	C	2	10	1	7.5	8.5
14-Jun-89	24	C	2	32	1	7.6	8.6
14-Jun-89	24	C	2	48	1	7.8	8.8
14-Jun-89	24	C	2	12	1	7.8	8.8
14-Jun-89	24	C	2	18	1	7.8	8.8
14-Jun-89	24	C	2	55	1	7.8	8.8
14-Jun-89	24	C	2	90	2	7.9	8.9
14-Jun-89	24	C	2	8	2	7.9	8.9
14-Jun-89	24	C	2	39	2	7.9	8.9
14-Jun-89	24	C	2	74	2	7.9	8.9
14-Jun-89	24	C	2	28	2	7.9	8.9
14-Jun-89	24	C	2	47	2	8.1	9.0
14-Jun-89	24	C	2	91	2	8.1	9.0
14-Jun-89	24	C	2	83	2	8.1	9.0
14-Jun-89	24	C	2	5	2	8.1	9.0
14-Jun-89	24	C	2	7	2	8.1	9.0
14-Jun-89	24	C	2	66	2	8.2	9.1
14-Jun-89	24.	C	2	50	2	8.2	9.1
14-Jun-89	24	C	2	53	2	8.2	9.1
14-Jun-89	24	C	2	69	2	8.2	9.1
14-Jun-89	24	C	2	49	2	8.2	9.1
14-Jun-89	24	C	2	96	2	8.2	9.1
14-Jun-89	24	C	2	31	2	8.2	9.1
14-Jun-89	24	C	2	4	2	8.2	9.1
14-Jun-89	24	C	2	6	2	8.4	9.3
14-Jun-89	24	C	2	15	2	8.4	9.3
14-Jun-89	24	C	2	73	2	8.4	9.3
14-Jun-89	24	C	2	67	2	8.4	9.3
14-Jun-89	24	c	2	95	2	8.4	9.3
14-Jun-89	24	C	2	79	1	8.4	9.3
14-Jun-89	24	C	2	37	1	8.4	9.3
14-Jun-89	24	C	2	64	2	8.4	9.3
14-Jun-89	24	C	2	26	2	8.4	9.3
14-Jun-89	24	C	2	9	2	8.4	9.3

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	24	C	2	43	2	8.5	9.4
14-Jun-89	24	C	2	59	2	8.5	9.4
14-Jun-89	24	C	2	17	2	8.5	9.4
14-Jun-89	24	C	2	16	2	8.5	9.4
14-Jun-89	24	C	2	89	2	8.5	9.4
14-Jun-89	24	C	2	30	2	8.5	9.4
14-Jun-89	24	C	2	27	2	8.5	9.4
14-Jun-89	24	C	2	3	2	8.5	9.4
14-Jun-89	24	C	2	88	1	8.5	9.4
14-Jun-89	24	C	2	35	2	8.7	9.6
14-Jun-89	24	C	2	78	1	8.7	9.6
14-Jun-89	24	C	2	65	2	8.7	9.6
14-Jun-89	24	C	2	45	2	8.7	9.6
14-Jun-89	24	C	2	34	2	8.7	9.6
14-Jun-89	24	C	2	41	2	8.7	9.6
14-Jun-89	24	C	2	11	2	8.7	9.6
14-Jun-89	24	C	2	71	2	8.7	9.6
14-Jun-89	24	C	2	57	2	8.7	9.6
14-Jun-89	24	C	2	52	2	8.8	9.7
14-Jun-89	24	C	2	46	2	8.8	9.7
14-Jun-89	24	C	2	80	2	8.8	9.7
14-Jun-89	24	C	2	87	2	8.8	9.7
14-Jun-89	24	C	2	24	2	8.8	9.7
14-Jun-89	24	C	2	33	1	8.8	9.7
14-Jun-89	24	C	2	58	2	8.8	9.7
14-Jun-89	24	C	2	75	2	8.8	9.7
14-Jun-89	24	C	2	68	2	8.8	9.7
14-Jun-89	24	C	2	36	2	9.0	9.8
14-Jun-89	24	C	2	23	2	9.0	9.8
14-Jun-89	24	C	2	60	2	9.0	9.8
14-Jun-89	24	C	2	93	2	9.0	9.8
14-Jun-89	24	C	2	77	2	9.0	9.8
14-Jun-89	24	C	2	85	2	9.0	9.8
14-Jun-89	24	C	2	86	2	9.1	9.9
14-Jun-89	24	C	2	76	2	9.1	9.9

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	24	C	2	22	2	9.1	9.9
14-Jun-89	24	C	2	82	2	9.1	9.9
14-Jun-89	24	C	2	29	2	9.1	9.9
14-Jun-89	24	C	2	94	2	9.1	9.9
14-Jun-89	24	C	2	14	2	9.1	9.9
14-Jun-89	24	C	2	72	2	9.1	9.9
14-Jun-89	24	C	2	42	2	9.1	9.9
14-Jun-89	24	C	2	51	2	9.3	10.1
14-Jun-89	24	C	2	44	2	9.3	10.1
14-Jun-89	24	C	2	97	2	9.3	10.1
14-Jun-89	24	C	2	19	2	9.3	10.1
14-Jun-89	24	C	2	40	2	9.4	10.2
14-Jun-89	24	C	2	92	2	9.4	10.2
14-Jun-89	24	C	2	56	2	9.4	10.2
14-Jun-89	24	C	2	25	2	9.4	10.2
14-Jun-89	24	C	2	61	2	9.4	10.2
14-Jun-89	24	C	2	2	2	9.4	10.2
14-Jun-89	24	C	2	63	2	9.4	10.2
14-Jun-89	24	C	2	54	2	9.4	10.2
14-Jun-89	24	C	2	21	2	9.6	10.3
14-Jun-89	24	C	2	38	2	9.6	10.3
14-Jun-89	24	C	2	84	2	9.6	10.3
14-Jun-89	24	C	2	13	2	9.7	10.4
					MEAN	8.6	9.5
					SD	0.5	0.5
					N	94	94
14-Jun-89	24	C	1	1	2	11.5	12.0
					MEAN	11.5	12.0
					SD		
					N	1	1
14-Jun-89	25	D	2	17	2	7.0	8.1

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	25	D	2	63	1	7.0	8.1
14-Jun-89	25	D	2	16	2	7.2	8.3
14-Jun-89	25	D	2	41	2	7.3	8.4
14-Jun-89	25	D	2	27	2	7.3	8.4
14-Jun-89	25	D	2	9	2	7.3	8.4
14-Jun-89	25	D	2	45	1	7.3	8.4
14-Jun-89	25	D	2	2	1	7.5	8.5
14-Jun-89	25	D	2	67	2	7.5	8.5
14-Jun-89	25	D	2	71	1	7.5	8.5
14-Jun-89	25	D	2	55	2	7.5	8.5
14-Jun-89	25	D	2	29	2	7.6	8.6
14-Jun-89	25	D	2	94	1	7.6	8.6
14-Jun-89	25	D	2	60	2	7.6	8.6
14-Jun-89	25	D	2	100	2	7.6	8.6
14-Jun-89	25	D	2	80	2	7.6	8.6
14-Jun-89	25	D	2	54	2	7.8	8.8
14-Jun-89	25	D	2	85	2	7.8	8.8
14-Jun-89	25	D	2	26	2	7.8	8.8
14-Jun-89	25	D	2	61	2	7.9	8.9
14-Jun-89	25	D	2	62	1	7.9	8.9
14-Jun-89	25	D	2	93	2	7.9	8.9
14-Jun-89	25	D	2	50	1	7.9	8.9
14-Jun-89	25	D	2	87	2	8.1	9.0
14-Jun-89	25	D	2	99	1	8.1	9.0
14-Jun-89	25	D	2	15	2	8.2	9.1
14-Jun-89	25	D	2	78	2	8.2	9.1
14-Jun-89	25	D	2	58	2	8.2	9.1
14-Jun-89	25	D	2	13	2	8.2	9.1
14-Jun-89	25	D	2	35	2	8.2	9.1
14-Jun-89	25	D	2	21	2	8.2	9.1
14-Jun-89	25	D	2	8	2	8.2	9.1
14-Jun-89	25	D	2	42	2	8.2	9.1
14-Jun-89	25	D	2	44	2	8.4	9.3
14-Jun-89	25	D	2	83	2	8,4	9.3
14-Jun-89	25	D	2	4	2	8.4	9.3

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
14-Jun-89	25	D	2	84	2	8.4	9.3
14-Jun-89	25	D	2	76	2	8.4	9.3
14-Jun-89	25	D	2	82	2	8.4	9.3
14-Jun-89	25	D	2	91	2	8.4	9.3
14-Jun-89	25	D	2	53	2	8.4	9.3
14-Jun-89	25	D	2	39	2	8.5	9.4
14-Jun-89	25	D	2	10	2	8.5	9.4
14-Jun-89	25	D	2	72	2	8.5	9.4
14-Jun-89	25	D	2	70	2	8.5	9.4
14-Jun-89	25	D	2	68	2	8.5	9.4
14-Jun-89	25	D	2	30	2	8.5	9.4
14-Jun-89	25	D	2	34	2	8.7	9.6
14-Jun-89	25	D	2	56	2	8.7	9.6
14-Jun-89	25	D	2	64	2	8.7	9.6
14-Jun-89	25	D	2	57	2	8.7	9.6
14-Jun-89	25	D	2	1	2	8.7	9.6
14-Jun-89	25	D	2	22	2	8.7	9.6
14-Jun-89	25	D	2	81	2	8.7	9.6
14-Jun-89	25	D	2	20	2	8.7	9.6
14-Jun-89	25	D	2	31	2	8.7	9.6
14-Jun-89	25	D	2	3	2	8.7	9.6
14-Jun-89	25	D	2	88	2	8.7	9.6
14-Jun-89	25	D	2	47	2	8.7	9.6
14-Jun-89	25	D	2	90	2	8.7	9.6
14-Jun-89	25	D	2	12	2	8.7	9.6
14-Jun-89	25	D	2	89	1	8.8	9.7
14-Jun-89	25	D	2	24	2	8.8	9.7
14-Jun-89	25	D	2	96	2	8.8	9.7
14-Jun-89	25	D	2	32	2	8.8	9.7
14-Jun-89	25	D	2	77	2	8.8	9.7
14-Jun-89	25	D	2	11	2	8.8	9.7
14-Jun-89	25	D	2	7	2	8.8	9.7
14-Jun-89	25	D	2	38	2	8.8	9.7
14-Jun-89	25	D	2	33	2	8.8	9.7
14-Jun-89	25	D	2	19	2	9.0	9.8

Appendix E. Lengths of herring larvae in Port Moller, 1989.

Date	Sample number	Site	Cohort	Fish number	Yolk	Measured length (mm)	Capture-corrected length (mm)
					MEAN	12.0	12.5
					SD		
					N	1	1
			2 GRAND		MEAN	8.6	9.5
					SD	0.7	0.6
					N	645	645
			1 GRAND		MEAN	11.6	12.1
					SD	0.6	0.5
					N	9	9

Notes:

1. Yolk: 1 = yolk sac, 2 = no yolk sac.
2. Site codes from Table 1.
3. Fish number refers to the order in which the fish were randomly chosen for measurement.
4. Corrected length = measured L* EXP(0.91*EXP(-0.26 *measured L)).
5. Fish were assigned to a cohort based on their corrected length:

	cohort 2	cohort 1
June 11	6.5-10.7	>10.7
June 12	7.9-11.0	>11.0
June 13	6.9-11.3	>11.3
June 14	7.7-11.6	>11.6

Appendix F : Correction factors for fish larvae density

This appendix reviews three methods of correcting measured densities of Pacific herring larvae for the probability of capture by a towed plankton net.

The most widely used method is to calculate the ratio of the density of fish larvae caught at night to the density of larvae caught during the day. The densities measured at night are assumed to approximate true densities because larvae are less able to detect and evade the net during the night than during the day. Three sets of night/day catch ratios of herring larvae have been reported in the literature. McGurk (1989a) reported the only set of night/day ratios that are currently available for Pacific herring larvae. They were measured with a 40 cm diameter bongo net equipped with a 1.5 m long net with a mesh width of 471 pm. The net was towed at about 2 to 3 kn. Brander and Thompson (1989) reported night/day catch ratios of Atlantic herring larvae captured by high-speed tow nets in the North Sea during the International Herring Larval Surveys. The net was a modified Gulf III sampler with a mouth diameter of 20 cm and a mesh width of 270 μm. It was towed at a speed of 5 kn. Heath et al. (1987) reported a single night/day ratio for Atlantic herring larvae of an average length of 11 mm captured off the north coast of Scotland. The efficiency of a 1 m diameter ring net with a mesh width of 250 μm was 3.14 times higher at night than during the day. The net was towed at a speed of 2 to 3 kn.

In order to compare the three data sets, the lengths of the Atlantic herring larvae were corrected for shrinkage due to capture in a towed net using McGurk's (1985) correction equation. The lengths of McGurk's (1989a) larvae were already corrected using the same equation. A covariance analysis showed that all three sets of data had the same intercept, but that Brander and Thompson's (1989) catch ratios increased with length at a significantly ($P < 0.01$) lower rate than either McGurk's (1989a) or Heath et al.'s (1987) catch ratios (Fig. F1). Therefore, a separate highly significant ($P < 0.001$) regression was fit to Brander and Thompson's (1989) data (Table F1). The difference in slopes is probably due to the difference in towing speeds; larvae were less able to evade the high-speed net used in the International Herring Larvae Surveys than the lower-speed nets used by Heath et al. (1987) and McGurk (1989a). Since a low-speed net was used to sample the plankton of Port Moller, McGurk's (1989a) equation was most applicable to this study.

The major assumption of the night/day catch ratio method is that the catch efficiency of the night tows is 100%. However, McGurk (1989a) reported that this assumption was not correct for Pacific herring larvae longer than about 18 mm in length. At that size the burst speeds of the fish may be great enough to enable them to evade a towed net even when their reaction distance to the net is reduced by darkness. The critical length

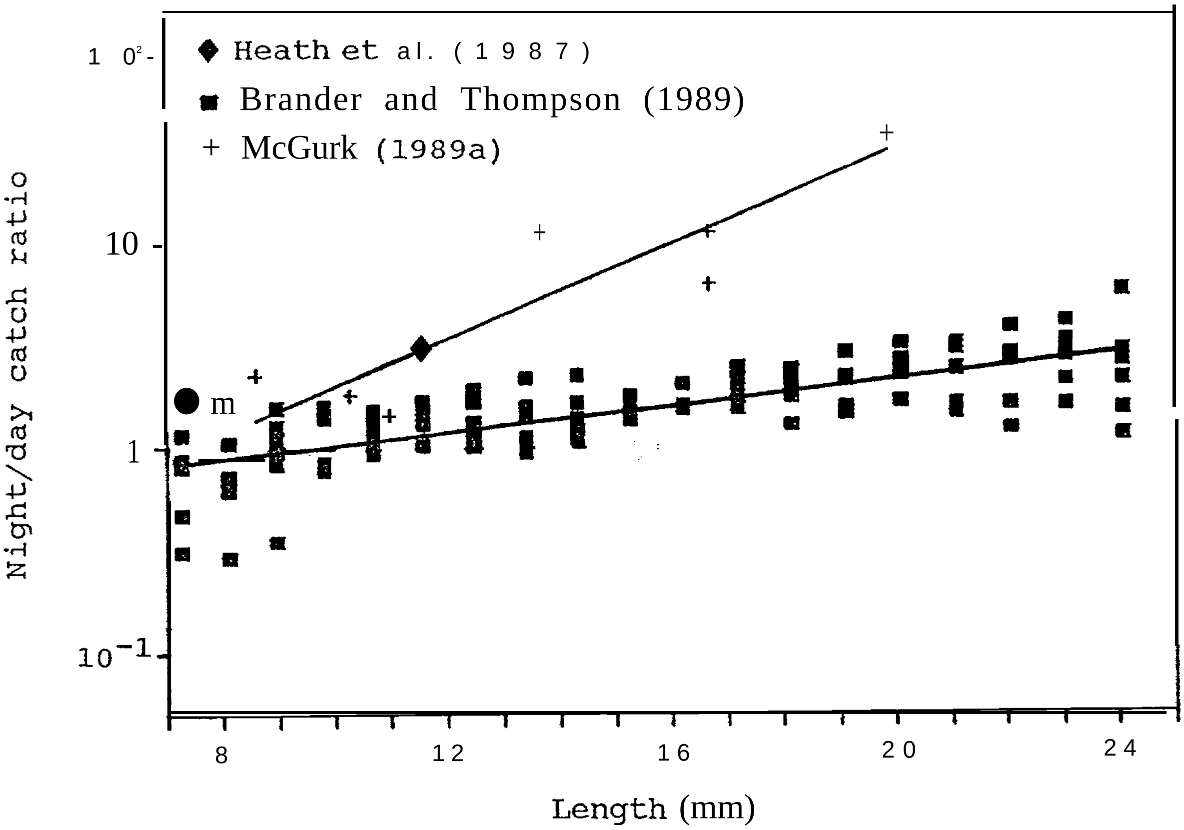

Fig. F1. Ratios of larval density measured at night to density measured during the day for herring larvae captured with low-speed towed nets (Heath et al. 1987, McGurk 1989a) and with high-speed nets {Brander and Thompson 1989).

is less than 18 mm in other species; for example Houde (1977a) reported that the night/day catch ratios for round herring, Etrumeus teres, larvae increased over the length range of 3 to 13 mm, but then declined in fish longer than 13 mm. The declining right-hand limb of this curve was presumably due to the evasion of the towed net at night. Therefore, the other two methods of correcting catches for net evasion are examined below in order to assess their usefulness compared to night/day catch ratios.

The second method of measuring catch efficiency is to compare two different types of sampling gear. Murphy and Clutter's (1972) study is the best example available. They compared catches of Hawaiian anchovy, Stolephorus purpureus, larvae taken with a 1 m diameter towed plankton net (333 μm mesh width) with catches taken by a plankton purse seine (333 μm mesh width) at the same site and time. The ratios of purse seine to tow net catches showed that the day plankton net catches underestimated the density of anchovy larvae in all length classes greater than 3.5 mm. The ratios of catches taken at night showed that the night plankton net catches also underestimated the density of anchovy larvae, but only in length classes greater than 19.5 mm. Murphy and Clutter's (1972) estimates of the catch efficiency of a towed plankton net were used by Yamashita et al. (1985) and Leak and Houde (1987) to corrected the measured densities of Japanese sand eel, Ammodytes uersonatus, and bay anchovy, Anchoa mitchilli, respectively, for net evasion. Therefore, their study is reviewed in detail in this section of the report.

Murphy and Clutter's (1972) method is based on the assumptions that the catch efficiency of a plankton purse seine is 100%, and that the daytime tows of the towed plankton net were conducted using standard methods. However, a comparison of their night/day ratios for the towed net and their purse seine/tow-net ratios with the night/day ratios of towed nets reported by other authors suggests that the second assumption may not have been valid. Table F1 tabulates the regressions of In(night/day ratios) on length for 10 species of fish larvae. It shows that the slope of the regression of ln(purse seine/tow net) on length, 0.4947 mm^{-1}, for Hawaiian anchovy is the highest slope that has yet been measured. It is 40% higher than the next highest slope of 0.3533 mm^{-1} for northern anchovy, Engraulis mordax, larvae, and it is 289% higher than the mean slope of 0.1712 mm^{-1} for the 9 species of fish other than Hawaiian anchovy. The regression calculated from Murphy and Clutter's (1972) data predicts that only 9.6% of 8 mm long herring larvae and 0.3% of 15 mm long herring larvae would be captured by a towed plankton net.

If correct, Murphy and Clutter's (1972) data indicates that most reported densities of fish larvae underestimate the true densities by as much as an order of magnitude. However, an examination of the ratios of night to day catches of Murphy and Clutter's (1972) towed net suggests that these results may also have been due to unusually low

Table F1. Regressions of In-transformed ratios of night/day catches or purse seine/tow-net catches of fish larvae on length of larvae.

Species	Type of rat io	Length range (mm)	n	intercept	slope (SE)	r^2	P	Author	Comments
Sardinops sagax	N/D	4.75-21.25	15	0.1564	0.1264 (0,0145)	0.85	<0.01	Ahlstrom (1954)	data from 1940-41 and 1950-51; all data used
Sardinops sagax [1]	N/D	2.50-21.20	17	-0.5318	0.1381 (0,0185)	0,79	<0,01	Lenarz (1973)	data from 1951 -60; all data used
Stolephorus purpureus	N/D	3.50-14.50	12	-3.5328	0.6546 (0.0624)	0.92	<0,01	Murphy and Clutter (1972)	all data used
Stolephorus purpureus	PS/TN	1,50-14.50	14	-1,6205	0.4947 (0.0537)	0,87	<0.01	Murphy and Clutter (1972)	all data used
Merluccius productus	N/D	2.00-18.10	26	0,2974	0.0212 (0.0249)	0.03	>0.05	Lenarz (1973)	data from 1966; all data used
Trachurus symmetricus	N/D	2.00-5.50	8	-0.6099	0.1886 (0.0431)	0,76	<0.01	Lenarz (1973)	data from 1966; data truncated at L=5.5 mm
Engraulis mordax	N/D	3.00-10.75	8	-1.8357	0.3533 (0,0255)	0,97	<0.01	Lenarz (1973)	data from 1951-60; data truncated at L=l 0.75 mm
Etrumeus teres	N/D	3.00-13.00	6	-0.5031	0.1381 (0,0268)	0.87	<0.01	Houde (1977a)	data truncated at L=1 3.0 mm
Opisthonema oglinum	N/D	1,50-16,50	16	-1.0894	0.2507 (0.0365)	0,77	<0.01	Houde (1977b)	all data used
Harengula jaguana	N/D	2.00-18.00	9	-0.2160	0.0546 (0.0323)	0,30	>0,05	Houde (1977c)	all data used
Clupea harengus harengus	N/D	6.00-24.00	103	-0,5648	0.0665 (0,0061)	0.54	<0.01	Brander and Thompson (1 989)	all data used
Clupea harengus pallasi	N/D	8.00-20.00	7	-1.9990	0,2700 (0.0580)	0.81	<0.01	McGurk (1989a)	all data used

Notes:

1, Only the ascending left-hand limb of the curve of In(ratio) on length was used.

2. N/D = night/day ratios, PS/TN = purse seine/tow-net ratios.

catches of anchovy larvae in day plankton-net tows. Table F1 shows that the slope of the regression of In(night/day catches) on length for Hawaiian anchovy larvae is 0.6546 mm^{-1}, which is 185% higher than the second highest night/day slope, and 382% higher than mean night/day slope. Such an unusually high slope suggests that the day plankton-net tows were performed in a non-standard method. At the very least, this analysis indicates that using night/day catch ratios or purse seine/tow net catch ratios from one species to correct densities of fish larvae of another species may lead to very large errors in estimating the true abundance of fish larvae.

The third method of correcting the density of fish larvae for net evasion is a mathematical model that relates the probability of capture to the radius of the towed net, to the size and burst swimming speed of a larva, and to water temperature. This model was developed by Clutter and Anraku (1968) and extended to Atlantic mackerel, <u>Scomber scombrus</u>, larvae by Ware and Lambert (1985). Its major assumption concerns the dependence of burst swimming speed on the length of a fish larva and on water temperature. Clutter and Anraku (1968) proposed that the probability of capture of a larva is determined by

$$(1)\quad p = 1 - \frac{1}{\pi R^2}\left[a\left(R^2 - \frac{a^2}{4}\right)^{0.5} + 2R^2 \sin^{-1}\left(\frac{a}{2R}\right)\right]$$

where p = probability of capture, R = radius of net (cm), and a = the distance (cm) larvae move between the time they react to the net and the time that the net reaches their plane. The distance moved in time T_r is

$$(2)\quad a = QL^b$$

where Q = f T_r, f = a temperature-dependent coefficient (s^{-1}), L = length (cm) of fish larva, and b = a coefficient with a value of approximately 2.42 [see Ware and Lambert (1985) for reasons supporting the choice of this exponent and other parameter values]. Since p approaches zero as a approaches the diameter of the net, 2R, then equation (2) can be rearranged to obtain

$$L_{max} = \frac{2R^{0.41}}{Q}$$

where L_{max} = the longest larva that can be captured. Thus, Q can be estimated from

$$(3) \quad Q = \frac{2R}{L_{max}^{2.42}}$$

Q is adjusted for the effects of water temperature by assuming a Q_{10} of 2, i.e. it doubles for every 10°C change in temperature.

The applicability of this model to Pacific herring larvae was examined by calculating the change in catch ratio (= I/p) with length for the herring larvae of Bamfield Inlet, B.C., that were studied by McGurk (1989a), and comparing it with the night/day catch ratios he reported. The radius of a bongo net was assumed to be 20 cm because the two ring nets that comprise the bongo net are assumed to fish independently of each other. L_{max} was estimated to be 2.3 cm from the catch curve for larva caught by day plankton net tows (McGurk 1989a: Fig. 1). Thus, Q = 5.33 at an median water temperature of 11*C. Fig. F2 shows that the envelope of modelled catch ratios for the temperature range of 8 to 14°C coincides with the average night/day ratio at the extremes of the range of fish lengths: 8 mm and 20 to 24 mm, but that the envelope underestimates the catch ratio between these extremes.

In summary, McGurk's (1989a) night/day catch ratios appear to be the most reliable method of correcting observed densities of Pacific herring larvae in Port Moller for the effect of net evasion. Murphy and Clutter's (1972) purse seine/plankton net catch ratios are too large to be reasonable, and there is too much unexplained variability between the night/day ratios of other species for their results to be applicable to herring larvae. Although Ware and Lambert's (1985) mathematical model predicts catch ratios of small and large larvae that are very similar to those reported by McGurk (1989a), their model underestimates the catch ratios for mid-size herring larvae.

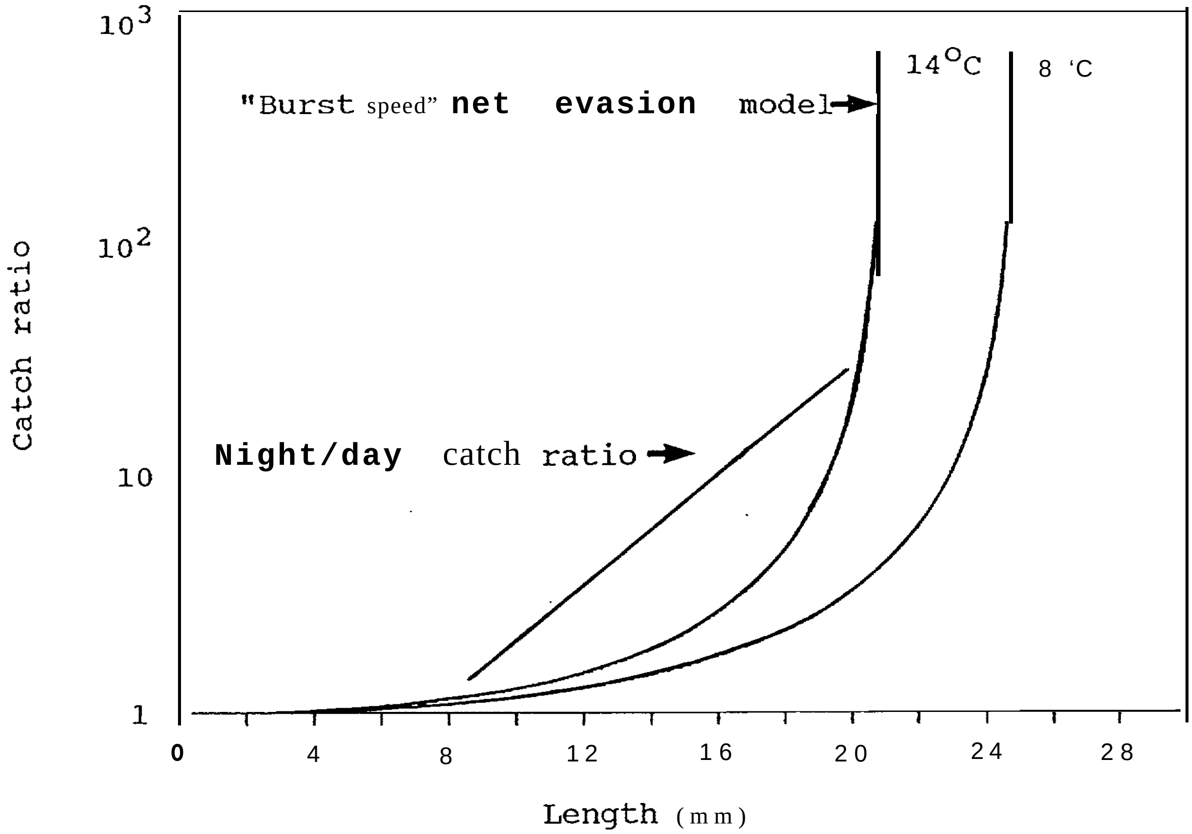

Fig. F2. Size-dependence of catch ratios of Pacific herring larvae calculated from McGurk's (1989a) night/day catch ratios and from Ware and Lambert's (1985) "burst speed" net evasion model (L_{max} = 23 mm, R = 200 mm, T = 11°C) over the temperature range of 8 to 14°C.